METALLURGIA

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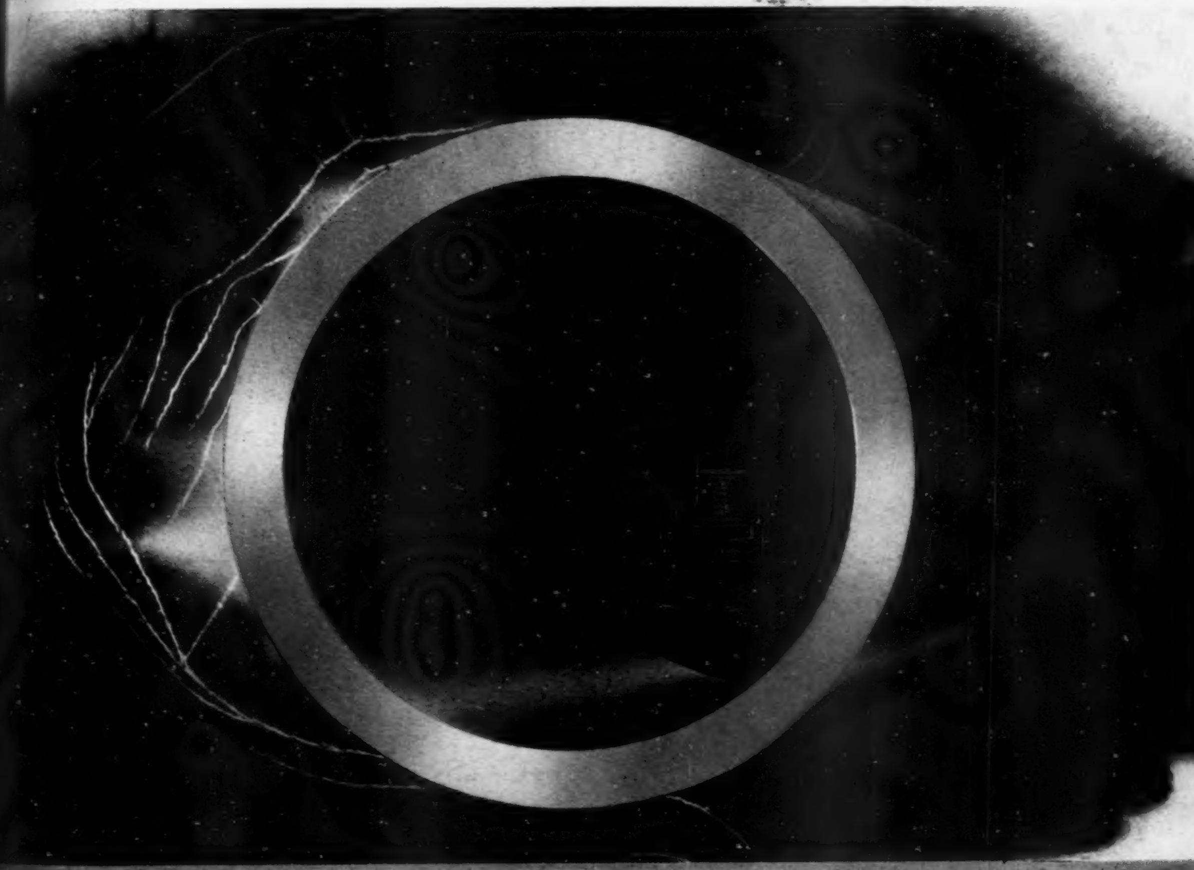

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INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

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NOVEMBER, 1953 Vol. XLVIII. No. 289

Fuel Economy

THE Fuel Efficiency Exhibition at the City Hall, Manchester, this month emphasises once again the importance of this matter in relation to the national economy. The survival of Britain as an advanced and developed State requires a continued expansion in industrial activity, and it is decidedly unlikely that coal output will expand in step. In fact, her total orthodox fuel supplies may not do so, and it is, therefore, essential that the present dissipation of her limited deposits of fuel should be brought to a halt. This can only be ensured by the adoption of a constructive long-term national fuel policy drawn up with due regard to all aspects of the production and consumption of fuel.

In a paper on the conservation of the nation's fuel and power resources to be presented to the Institute of Fuel this month, Dr. F. M. H. Taylor puts forward a fuel plan based on information collated from a wide variety of sources, including the nationalised fuel industries, large fuel users, prominent consulting engineers and officials in Government Departments. In the past, proposals have been put forward by sectional interests—the coal, gas or electricity supply industries—for solving Britain's fuel problems in terms of the particular type of service that one or the other of these industries has to offer to the consumer. Dr. Taylor, on the other hand, is concerned to ensure that any proposals that are made for improvement shall be consistent with the Government's overall economic policy, and will benefit the nation as a whole. Thus in settling what amount of capital shall be invested in the fuel production and distribution industries and in plants for improved fuel utilisation, account must be taken of the expected savings of money and coal in each case.

The price of the coal supplied to the two competing industries, gas and electricity, has in the past been fixed by the Coal Board alone, latterly in accordance with its new price structure. Dr. Taylor favours the modification of this practice on the ground that it permits the Board to control the economic development of both the gas and electrical industries—industries which in many respects compete with raw coal. In the national interest, the price structure should be subject to independent supervision, e.g., by a Fuel Advisory Committee, which would ensure stable prices and the true economic development of electricity, gas and coke.

The Committee would also verify that the policy of truly equating prices charged with costs of production and distribution was actually carried out. The Government's present policy of improving financial incentives to industrialists installing fuel economy plant is commended, and the question of marginal coal, produced and sold at a loss in order to satisfy the excessive demands of the more wasteful fuel users, is clearly set out as one of today's most pressing problems.

Dr. Taylor stresses the need for publication at intervals of the types and grades of coal and the quantities which the Coal Board expect to produce in the subsequent 5- or 10-year period, to ensure that installers of expensive plant may know in advance what fuel they can expect to receive. The constant and reliable supply of fuels to users installing special plant is necessary to avoid scrapping such plant, and loss of confidence in industry generally.

The main conclusion of Dr. Taylor's paper is that by the use of already well-known methods of fuel and power utilisation, substantial savings can be effected, and increased supplies of heat and power be made available for the urgent task of increasing the productivity of British industry. Whilst this is undoubtedly true, the problem remains as to how the improvements can be put into effect. The individual manager in industry is faced with economic decisions which he must justify in the end by the arithmetic of his own business. When he considers the use of fuel in his works he has to balance the current waste against the capital outlay that would be needed to correct it. Woolly talk about fuel saving as a " top priority " does not help him. As is stated in an interesting article on " When to Save Coal " which appears in the November issue of *Trend**, fuel saving enjoys no self-evident primacy over the other requisites of industrial progress, and it would be better not to talk as if it did. The article goes on to point out that Britain's industrial economy was built up on plenty of cheap coal, aggressively mined and fed with abandon into gloriously wasteful contraptions, many of which would never wear out and are still in fact at work. For the future, coal will be obtained in large quantities only by the work of highly paid miners assisted by very costly capital investments, and there seems to be little chance of any fall in the price of coal in the near future. It has been said that, even at current prices, coal is too cheap, a statement with which neither domestic nor industrial consumers could be expected to agree. It is true, however, that the more expensive it becomes the greater is the incentive to economise in its use, and for this reason rising prices may not be a wholly bad thing. In such circumstances, the chances are that fuel saving modifications which will hardly pay their way to-day will be saving large sums in a few years time. Considerable economies can be effected, as the experience of the Ministry of Fuel and Power advisory service has shown, by quite small, inexpensive changes, both in the boiler house and the steam distribution system, but savings of the order of 15–20% nationally will not be achieved without substantial capital investment. The loan scheme of the Ministry of Fuel and Power for fuel-saving improvements in industry can be of considerable help in such cases, providing as it does for repayment over a period up to 20 years, with the first two years interest-free.

* Prepared for Everett's Advertising, Ltd., 10 Hertford Street, London, W.1., by the Economist Intelligence Unit.

New and Revised British Standards

Methods for the Analysis of Iron and Steel (B.S.1121)

Part 2: Determination of Nickel in Permanent Magnet Alloys, Price 2s.

Part 4: Determination of Aluminium in Permanent Magnet Alloys, Price 2s. 6d.

Part 5: Determination of Copper in Permanent Magnet Alloys, Price 2s.

Part 29: Determination of Sulphur in Basic Steelmaking Slags (Gravimetric Method), Price 2s.

The first of these British Standards are revisions of editions published some five years ago, but Part 29 is new. Each part specifies the apparatus and reagents required and the procedure for analysis and standardisation.

The principle of the method for the determination of nickel in permanent magnet alloys is the removal of copper as copper sulphide, from a reduced solution of the alloy. Nickel is then precipitated with dimethylglyoxime and determined cyanometrically. The method is applicable within the range of 7–35% of nickel. The reproducibility is $\pm$ 0·10% with 15% of nickel and $\pm$ 0·20% with 30% of nickel.

The principle of the method for determining aluminium in permanent magnet alloys is to remove interfering elements by electrolysis using a mercury cathode and by precipitation with cupferron. Aluminium is precipitated with 8-hydroxyquinoline and determined either gravimetrically or volumetrically. The method is applicable within the range of 5–15% of aluminium with a reproducibility of $\pm$ 0·15% of aluminium.

The principle of the method for the determination of copper in permanent magnet alloys is to precipitate the copper, with hydrogen sulphide, from a reduced solution of the alloy and finally to determine the copper iodometrically. The method is applicable within the range of 0·5–8·0% copper. Reproducibility is $\pm$ 0·10% with 8% of copper and $\pm$ 0·05% with 5% of copper.

The principle of the gravimetric determination of sulphur in basic steelmaking slags is to convert the sulphur compounds in the slag to sulphate in the presence of a powerful oxidising agent and an alkali salt. The siliceous residue is filtered off and any sulphur present is extracted. The total sulphur is precipitated as barium sulphate. The method can be applied to all basic steelmaking slags and gives a reproducibility of $\pm$ 0·015%.

Certified Samples for Metallurgical Analysis (B.S.1548:1953) Price 2s.

This revised edition describes the general conditions to be complied with in regard to the preparation, analysis, packing and storage of certified samples, in order that they may qualify for the B.S.I. certification mark, indicating that their composition is in accordance with a certificate of analysis supplied with each sample.

Mild Steel Drums: Heavy and Light Duty—Removable Heads (B.S.2003 : 1953), Price 3s.

This further standard in the series covering mild steel drums deals with heavy and light duty full open top drums with removable heads. The drums are subdivided into four classes, but it will be appreciated that a standard of this kind must cover so many types that it remains essential for users to ensure that the gauge of metal they select for a particular drum is adequate for the performance required.

Copper Tubes for General Purposes (B.S.2017:1953) Price 3s.

There have previously been published a number of standards for copper tubes for specialised uses, which in most cases include fully dimensioned tables of sizes of tubes to which the standards apply. The need has been felt, however, for a standard for copper tubes which would meet the requirements of general users who find it difficult to select suitable sizes from the dimensional tables in existing standards and who may often prefer to specify copper tubes by the outside diameter required, normally expressed in inches and fractions of an inch, and by the required thickness, normally in imperial standard wire gauge numbers. It is believed that the standard in the form now presented should meet the needs indicated above, including, among others those of users in the automobile, petroleum and refrigeration industries, from whom requests have previously been received for a new standard to meet their special requirements.

In many instances, tubes for general usage are required for connection by fittings involving a close fit between the outside of the tube and the socket of the fitting. It has been considered desirable, therefore, to include two ranges of tolerances on outside diameter. Table 2 providing for the usual plus and minus tolerances, and Table 3 providing for a limited minus tolerance only to meet the conditions required for connection by the types of fittings mentioned. It has been found necessary to confine the application of the closer range of tolerances on diameter to a preferred list of sizes from $\frac{1}{8}$ in. to 2 in. outside diameter which is given in Appendix A.

With a view to promoting a reduction in the number of sizes demanded it is hoped that users will endeavour to select their tube sizes up to 2 in. outside diameter from the list of preferred sizes in Appendix A, irrespective of the range of tolerances on diameter which is required. The standard indicates a preferred method of designating tubes for general purposes which it is hoped will be followed by users wherever practicable.

Appendix B gives tables of sizes of copper tubes for general purposes required for screwed connections, taken from B.S.61, Part 1. Appendix C gives a table of sizes of copper tubes for the petroleum industry. These sizes have been selected from Table 5 and 6 of B.S.1306, Part 2, "Seamless Copper Tubes for Steam Services," with the exception of the $2\frac{1}{2}$ in. size which is similar to the corresponding size in A.S.T.M. B.42. Additional provisions to meet the special conditions of the refrigeration industry are included separately in Section 2.

Copper Plates for General Purposes (B.S.2027:1953) Price 2s. 6d.

This standard applies to rolled copper plate in the annealed condition in thicknesses over $\frac{3}{8}$ in. and over 12 in. in width. It specifies quality of material, tolerances and mechanical properties and includes details of mechanical testing.

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1. Price 3s.

The Development of a Copper-Silver-Lead Alloy for Bearings

By G. Llewelyn, B.Sc., A.I.M.
The Bristol Aeroplane Co., Ltd.

Preliminary tests have shown that a copper-silver-lead alloy containing 30% copper, 30% silver and 40% lead possesses most of the usual properties associated with bearing alloys. No difficulties are associated with the casting and bonding qualities, whilst the general "bearing" properties are equal to, and in some instances better than, those of the present day alloys. The improved mechanical properties at temperature should enable the alloy to be used under heavier loads and should minimise the danger of fatigue failure.

THE rapid development of the internal combustion engine has increased the difficulties of power transmission, because crankshafts rotate at higher speeds, carry heavier loads and generally operate under more severe conditions. As the properties desired in an ideal bearing alloy for such engines are well known, there is no need to discuss them here. The bearing alloys in use to day satisfy the majority of these requirements, but there are a few which are not satisfied, and these in certain respects limit the use of the alloys.

Although the tin-base alloys were discovered as long ago as 1839, they still remain the most widely used bearing alloys. They are easily bonded to steel or bronze shells, and possess very good embeddability qualities and anti-friction properties, whilst their resistance to corrosion by oil, acids and other oxidation products is remarkable. Unfortunately, their compressive and fatigue strengths at the operating temperature prevailing in high speed engines are very low. During running, fatigue cracks are liable to develop as a network on the surface and, at a later stage, to penetrate into the bearing alloy, forming "loose-tiles" which destroy the oil film. Efforts have been made to overcome this by reducing the thickness of the lining, but, with these ultra-thin linings, manufacturing difficulties increase considerably, and, in addition, a stage will be reached where there will be insufficient depth of whitemetal to accommodate foreign particles. A great deal of work has also been carried out in an effort to effect improvement by modifying the composition[1, 2], but with only limited success.

The cadmium-nickel and cadmium-silver alloys are well known, and have slightly better fatigue properties[3] at elevated temperatures than the tin-base alloys. However, these alloys have at least one serious limitation, i.e., susceptibility to corrosion by oil acids. The corrosion difficulties can be minimised by indium plating and diffusing at 150° C., thus forming a cadmium-indium alloy layer which is reasonably resistant to oil corrosion. Even this is only partially successful, as it has been found that the indium tends to combine with the nickel rather than with the cadmium, forming a nickel-indium compound with detrimental effects upon structure and performance. Moreover, the use of cadmium-base alloys is attended by technical difficulties, due primarily to the rapid rate of oxidation of these alloys in the molten condition. Certain steps can be taken to minimise this, but even so the rate of loss by drossing is a serious consideration. Bonding with the bearing shell is much more difficult to effect than is the case with the tin-base alloys.

A considerable amount of work has been done on aluminium-base bearing alloys. In Germany, prior to 1939, efforts were concentrated on alloys containing iron, silicon, chromium, etc., thus forming alloys having the traditional hard particles embedded in the relatively soft aluminium-rich matrix. The other development has been in the direction of aluminium alloys containing a low melting point constituent, such as the A.C.9 alloy which contains tin. All these alloys have the disadvantage that they are relatively hard. Also, their elastic limits are low, so that when running they tend to lose their interference fit. In order to try and overcome this difficulty, many attempts have been made to evolve a method of lining steel shells with these alloys in the orthodox manner. Some measure of success has been achieved, but the practical difficulties are so great that for the time being they remain out of favour.

The silver bearings have been given much publicity, especially in America. They can either be cast, electro-deposited or rolled on to the steel shell. To counteract the unpredictable tendency of the silver to seize, lead plating was used at first, but subsequently lead plus indium plating was adopted in order to overcome corrosion difficulties associated with the lead itself. Great importance is attached to the high heat conductivity of the silver, but the full benefit of this property cannot be obtained because the silver is, in fact, effectively shielded from direct contact with the oil by the superimposed lead-indium layer. At working temperatures, the fatigue properties of the silver are very good. Nevertheless, its success as a bearing depends on the proper functioning of the lead-indium layer.

The copper-lead alloys used for bearings are, strictly speaking, mixtures of copper and lead, and as they are mechanically weak, they must be bonded to steel shells. The bonding can be accomplished quite readily provided excessive segregation of the lead can be avoided. These alloys possess high load-carrying capacities and good fatigue strength at working temperatures, but, unfortunately, they are not very tolerant of foreign matter. The main difference between the silver bearing and the copper-lead bearing is the fact that the silver depends on the behaviour of the lead-indium film : the copper-lead

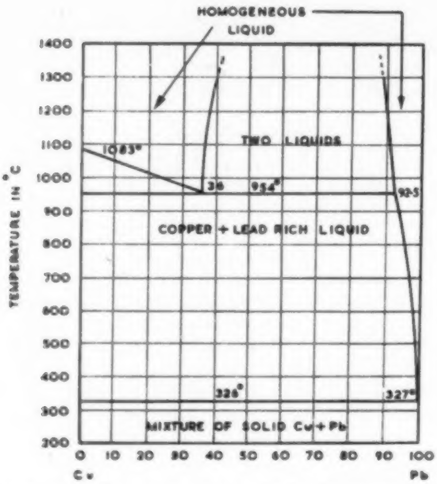


Fig. 1.—Copper-lead equilibrium diagram.

bearing, on the other hand, carries its own supply of lead. Under "emergency conditions," i.e., shortage of oil or excessive loading, some of this lead is extruded from the copper-lead lining and wiped over the surface, causing a drop in friction and in heat generation, with the restoration of more normal conditions. The extent to which this film mechanism operates depends on the lead content of the alloy and its mode of distribution. There are two main types of distribution, i.e., the discontinuous globular or "currant bun" type, and the dendritic type, where the lead is present as continuous strings between the copper dendrites. The type of structure depends on the manufacturing technique and the method of cooling. In either case, the thin lead film can be produced during running. This advantage should become more and more pronounced as the lead content of the lining increases.

Bowden and Tabor[4] have shown that thin films of lead deposited on copper-base alloys reduce the friction to a very low value. They consider that the anti-friction and anti-seizure properties of certain bearing alloys are due to the spreading over the surface of thin films of a soft low melting point constituent. They find that the friction between unlubricated metals is due, primarily, to the shearing of metallic junctions formed between the two metals, and to the ploughing effect of one metal through the other. The friction force F is expressed as the real area of contact A multiplied by the shear strength S of the softer metal.

$$F = AS$$

In the case of a hard metal sliding on a soft metal, the real area of contact is large, although the shear strength of the softer metal is low, so that A is large and S is small. With a hard metal sliding on a hard metal A is small and S is large. When, however, the hard metal slides on a very thin film of soft metal superimposed on a relatively hard base, both A and S are small, so that the frictional force is at a minimum. The present-day copper-lead alloys can be classed as "thin film" bearings, because in order to ensure a reasonable factor of safety, it is customary to deposit a thin coating of lead on the bearing surface before it goes into service. By increasing the lead content of the alloy, however, it should be possible to ensure the formation of a natural lead film on the surface during use.

It is well known that powder metallurgy techniques have been adapted quite successfully to the production of such high-lead, copper-lead alloys. The present paper describes work carried out in an attempt to produce a high-lead, copper-silver-lead alloy capable of being bonded to a mild steel shell using conventional casting techniques. Considerable difficulties can be anticipated with the casting of these alloys. Examination of the copper-lead equilibrium diagram[5] (Fig. 1) reveals the features which cause these difficulties. They are :—

(*a*) limited liquid miscibility, and
(*b*) very limited solid solubility.

With alloys containing more than 36% lead, a single liquid can only be obtained at very high temperatures. Work carried out by Claus[6] has shown that the presence of other elements has a marked influence on the range of the miscibility gap : silver, among other metals, can reduce it. Hence, by adding sufficient silver to any otherwise heterogeneous melt in the copper-lead alloy series, it should be possible to make it homogeneous and, therefore, capable of being cast on to steel shells by normal methods. In this way, alloys containing a higher lead content than usual could be produced for use as bearings.

Preparation of the Alloys

The metals used in the preparation of the various alloys were as follows :—

1 Oxygen-free high-conductivity copper in the form of 0·25 in. diameter rod.
2 99·99% silver in the form of droplets.
3 "Analar" lead in the form of ingots 4 in. × 2 in. × ¾ in. thick.

500-g. melts of these metals were made under a boric acid-cryolite flux in a small high frequency furnace. The copper was first melted, then the silver was added, the final addition, just prior to pouring, being the lead. No deoxidisers were used since the liberal flux covering reduced oxidation to a minimum. The pouring temperature varied from 1,100° C. to 1,140° C., depending on the composition of the alloy, the pouring being carried out direct from a bottom pouring plumbago crucible into small mild steel canisters of the type shown in Fig. 2. These canisters consisted of two concentric shells welded on to a mild steel ring which formed the base of the canister. The outer shell had a flange welded on to the top end for holding the canister whilst casting the metal into the annular space between the two shells. Two different sizes were used, the smaller one* for test pieces for adhesion and hardness tests, the larger† for test pieces for coefficient of friction and embeddability tests. Some importance was attached to the preparation of the canisters prior to casting : all canisters just prior to use were thoroughly degreased in trichlorethylene vapour, followed by shot blasting to ensure complete freedom from oxide and scale ; then they were filled with the boric acid-cryolite flux and heated slowly to 750° C. Preheating to this temperature enabled the flux to melt slowly and form a thin coating on the inside walls. Five minutes prior to pouring, the canisters were transferred to another furnace maintained at 1140° C., this time being the minimum required for the canisters to come up to the latter temperature. Longer periods at this high temperature caused the formation of a heavy scale

* 1⅝ in. I.D. of outer shell, 1⅛ in. O.D. of inner shell, 3½ in. long.
† 3 in. I.D. of outer shell, 2½ in. O.D. of inner shell, 5¾ in. long.

coating on the exposed walls, which gave rise to irregular cooling. After pouring, the canisters were rapidly cooled by means of an internal water spray placed inside the inner shell and moved along the length of the canister at a predetermined rate, the total time for solidification being approximately one minute. Approximately half an inch from the top and bottom of each canister was discarded, the remainder being machined so as to leave approximately one eighth of an inch of bearing alloy on the outside of the inner steel shell.

Numerous ternary alloys of widely varying compositions were prepared and cast in the manner already described. Hardness tests, using 20kg. load and 2 mm. ball, were carried out on all the alloys after rough machining. This was followed by further machining, leaving $\frac{1}{16}$ in. of bearing alloy on the shell for the adhesion test. The nominal compositions, hardness and bonding qualities of the alloys prepared are given in Table I.

Reviewing this table, and bearing in mind the object of the investigation, the following observations can be made.

(a) Silver-base alloys containing only small quantities of lead do not adhere to mild steel, and their hardness is rather high.

(b) Alloys containing 45% lead and over, with varying copper and silver contents, do not adhere strongly to mild steel.

(c) Copper-base alloys containing small quantities of lead adhere quite well, but their hardness is inclined to be rather high.

(d) Alloys containing 30–40% lead, 20–40% copper and 30–40% silver, bond quite well to mild steel, and also have hardness values which would enable them to be considered as bearing alloys.

TABLE I.—NOMINAL COMPOSITIONS, HARDNESS AND BONDING QUALITIES OF ALLOYS PREPARED.

Alloy	Nominal Percentage Composition: Copper	Silver	Lead	Brinell Hardness 20/2	Bonding Qualities
1	10	85	5	64·2	Poor
2	15	80	5	74·1	"
3	5	85	10	46·1	"
4	1	89	10	45·2	"
5	70	20	10	61·5	Good
6	80	10	10	54·3	"
7	85	5	10	40·7	"
8	89	1	10	39·4	"
9	22	64	14	74·9	Poor
10	45	50	5	59	Good
11	34	46	20	48·2	"
12	33	42	25	41·6	"
13	30	40	30	35·1	"
14	40	30	30	32·0	"
15	34	33	33	36·0	"
16	20	40	40	32	"
17	30	30	40	29·5	"
18	27·5	27·5	45	27·0	Weak
19	25	25	50	21·2	"
20	20	30	50	24·4	"
21	15	35	50	20·7	"
22	20	20	60	17·1	"
23	15	25	60	20·1	"
24	10	30	60	19·3	"
25	10	20	70	16	"
26	5	25	70	17·7	"

TABLE II.—COMPARISON OF MECHANICAL PROPERTIES.

Alloy	Test Temperature °C.	Ultimate Tensile Stress tons/sq. in.	Elongation %	Modulus of Elasticity lb./sq. in.
Copper-Silver-Lead Alloy (30% Cu, 30% Ag, 40% Pb)	20	6·3	—	$6·8 \times 10^6$
	100	4·6	1·0	$5·4 \times 10^6$
	150	4·4	1·0	$4·3 \times 10^6$
	180	4·3	1·5	$3·8 \times 10^6$
Tin-Base Alloy (3–4% Cu, 6·5–7·5% Sb, remainder Sn)	20	4·4	15·0	$7·61 \times 10^6$
	100	4·4		$6·05 \times 10^6$
	150			$3·8 \times 10^6$

Fig. 2.—Mild steel canister for casting.

Microscopic examination revealed that the alloys with equal amounts of copper and silver and of high lead content were quite free from lead segregation, whilst similar alloys with unequal amounts of copper and silver showed some tendency towards this defect. Thus, from this preliminary work, an alloy containing 30% copper, 30% silver and 40% lead appeared to be the alloy with the highest lead content which could be satisfactorily cast on to a steel shell in the conventional manner. Subsequent work entailed carrying out suitable tests on this alloy in order to compare its bearing qualities with present-day alloys.

Assessment of 30–30–40 Cu-Ag-Pb as a Bearing Alloy

The preliminary tests showed that this alloy could be bonded to a mild steel shell using standard casting techniques. No attempts were made to determine the actual bond strength, since the simple chipping test used gave a very good indication as to whether the bond was strong or weak.

Mechanical Properties

For determining the mechanical properties, one inch diameter bars were cast, using a cooling rate similar to that employed with the canisters. Suitable tensile test pieces 0·357 in. diameter with a gauge length of 2 in. were machined from these bars and tested on a Buckton single lever tensile machine, the load being applied at the rate of 1 ton/sq. in./min., and the extension for determining the modulus of elasticity was measured by means of a Tuckerman extensometer. For the elevated temperature tests, the test pieces were maintained at within ± 2° C. of the required temperature in a suitable furnace for one hour before applying the load. The results are shown in Table II, together with some results obtained by other investigators[7] on a tin-base alloy. The modulus of elasticity values obtained for the alloy compare quite favourably with those of the tin-base alloy, being slightly better at temperatures of 150° C

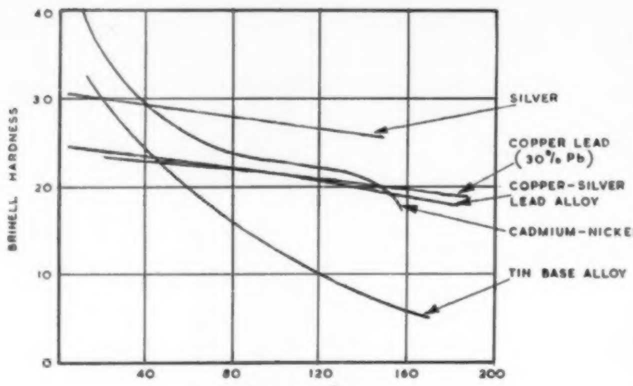


Fig. 3.—Hardness-temperature curves for various bearing alloys.

but still low enough to permit sufficient elastic deformation under designed loads.

The compressive strength at running temperatures was investigated by carrying out hardness tests at elevated temperatures. Several test pieces $\frac{7}{8}$ in. dia. × $\frac{1}{2}$ in. thick were machined from suitably cast bars of the alloy, together with similar test pieces from the other bearing alloys included in the test for comparison. The hardness tests were carried out on an Avery Brinell machine using a 500 kg. load and a 10 mm. ball. Slight modifications were made to the machine in order to accommodate a small furnace for carrying out tests at 100° C., 120° C. and 150° C. as well as at atmospheric temperature. Each specimen was soaked at the appropriate temperature for thirty minutes, the load then applied for fifteen seconds, and the specimen allowed to cool to room temperature before measuring the impression. The results on the copper-silver-lead alloy and on the other bearing metals are shown graphically in Fig. 3. It can readily be seen that the copper-silver-lead alloy retains its hardness at elevated temperatures far better than the tin-base alloy, the slope of the graph being identical with that of the 30% lead, copper-lead alloy which is well known for its high load carrying capacity.

Corrosion Resistance

It is a well known fact that the cadmium-base bearing alloys are very prone to corrosion during service, whilst the tin base alloys, on the other hand, have very good resistance to corrosion under similar conditions. In order to assess the anti-corrosive qualities of the copper-silver-lead alloy, comparison tests were carried out with the above alloys and a 30% lead, copper-lead alloy. Test pieces measuring $\frac{1}{8}$ in. × $\frac{1}{2}$ in. × $1\frac{1}{2}$ in. long were cast under similar conditions to those employed in producing bearings from the respective alloys. A small hole $\frac{1}{8}$ in. dia. was drilled in one end of each test piece for suspension in the oil corrosion rig. Eight specimens were mounted so as to form two adjacent four-bladed paddles on the shaft of an electric motor. Prior to testing, each test piece was weighed and its surface area measured and recorded: the oil (used engine oil) was maintained at 150° C. by means of a controlled electric heater. The test pieces were rotated in the hot oil for a period of 20 hours, which was considered to be long enough to assess the corrosion rates. The test pieces were then soaked in trichlorethylene to remove all traces of oil, dried and finally weighed. The corrosion rates expressed as the loss in weight in g./sq. cm. of surface area are given in Table III.

These results reveal that the corrosion rate of the copper-silver-lead alloy is much lower than the cadmium-nickel alloy, and is very similar to the standard copper-lead alloy, but is inferior to the tin-base alloy. However, it can be said that the rate of corrosion is comparatively low, and if at any time this should be considered excessive it could be reduced considerably by indium plating and heat treating to diffuse the indium into the lead.

Coefficient of expansion tests carried out on the copper-silver-lead alloy and some other well-known bearing alloys, over the range 20–200° C., revealed that there was nothing unusual in the behaviour of the alloy, thus indicating that no abnormal clearances etc. would have to be considered. The values obtained for the various alloys are given in Table III.

Wear Resistance

An Amsler wear machine was used to study the anti-friction qualities of the copper-silver-lead alloy. This test reveals whether there is any tendency to form a thin lead film on the surface during running, thus maintaining the coefficient of friction at a minimum. The principle of the machine is shown diagrammatically in Fig. 4. The circular test pieces A and B roll circumferentially on one another under load, and are mounted at the end of two parallel shafts. The shaft of the upper disc B rotates in a yoke, and is pressed against it by a spring. This spring determines the pressure with which the two discs roll over one another. The lower disc A is carried on a shaft D, driven by an electric motor. Between the shaft and the motor there is (1) a dynamometer which indicates on a graduated scale S the frictional resistance between the two discs, and (2) an integrating mechanism which records on a counter the mechanical work absorbed by the disc. The dynamometer consists of a pendulum C which the power transmitted causes to deviate from its vertical position of equilibrium. As the frictional torque between the test specimens increases, so does the throw on the pendulum and hence the pointer will give a higher torque reading on the scale. A recording drum is fitted so that a continuous record is obtained throughout the run. The coefficient of friction at any instant is given by

$$\mu = \frac{F}{N}$$

where $F = \dfrac{\text{Torque reading on scale (cm. kg.)}}{\text{Radius of lower specimen (cm.)}}$

N = Normal force (kg.) between the two specimens.

Tests were carried out on the copper-silver-lead alloy at room temperature.

The copper-silver-lead test rings were prepared from the larger of the canisters described previously. Machining was carried out so as to leave the rings with 0·0625 in. of bearing alloy on the shell, the surface having the same standard of finish as a production bearing. Each ring was pressed on to a mild steel disc in order to prevent any flexing during test. The other test disc of the same diameter and width, and representing the shaft against which the bearing would eventually run, was a carburised and heat treated nickel-chrome steel. The test pieces were lubricated at the commencement of the

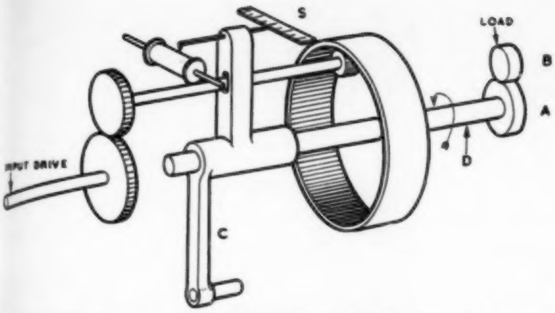


Fig. 4.—Diagrammatic representation of the Amsler wear machine.

test and then run until seizure occurred, or until 50 hours running had been completed. A load of 5 kg. was applied to the test pieces which were rotated in the same direction at a relative speed of 20 r.p.m. : the operation was carried out at room temperature. The result (Fig. 5) indicates that the movement is smooth and the coefficient of friction low which can be explained by the Bowden and Tabor[4] thin film theory. During sliding, the lead-rich phase is squeezed out and smeared over the surface, forming a thin film which will give a low friction value.

Accommodation of Hard Particles of Foreign Matter

The ability to accommodate any hard particles of foreign matter carried in the oil stream is a necessary and important property of bearing alloys. The tin-base alloys are renowned for their excellent accommodating qualities, but pure silver, especially if the lead-indium layer is removed, is very poor in this respect. In order to assess the copper-silver-lead alloy from this point of view, appropriate tests were carried out with the Amsler wear machine at room temperature. Similar test pieces to those prepared for the coefficient of friction tests were used, pure silver and white metal being included for comparison. Core sand introduced into the lubricating oil acted as " foreign matter." The contaminated oil was fed on to the test rings by means of a

TABLE III.—COMPARISON OF RESISTANCE TO CORROSION AND COEFFICIENT OF EXPANSION

Alloy	Loss in Weight after 20 hr. at 150° C. g./sq.cm. of surface area	Coefficient of Expansion (20–300° C.) × 10[6]
Tin-Base Alloy 6·0–7·5% Sb, 2·5–3·5% Cu, 2·25–3·35% Ag, remainder Sn	0·0004	25·5
Copper - Lead Alloy (30% Pb, 1% Ag, remainder Cu)	0·011	19·0
Copper-Silver-Lead Alloy (30% Cu, 30% Ag, 40% Pb)	0·013	22·5
Cadmium-Nickel Alloy (1·2–1·4% Ni, remainder Cd)	0·155	29·4

TABLE IV.—COMPARISON OF EMBEDDABILITY QUALITIES.

Alloy	Weight of Sand g./sq. cm.
Tin-Base Alloy (6·0–7·5% Sb, 2·5–3·5% Cu, 2·25–3·25% Ag, remainder Sn)	1·73
Cast Silver	0·55
Copper-Silver-Lead (30% Cu, 30% Ag, 40% Pb)	1·0

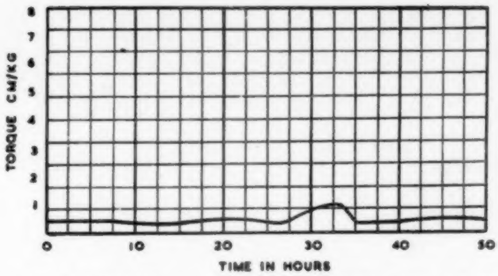


Fig. 5.—Coefficient of friction curve for the 30–30–40 copper-silver-lead alloy.

small closed chain resting on the shaft adjacent to the lower steel test piece and dipping into the loaded oil bath immediately underneath. This chain rotating on the shaft fed the oil on to the test piece. Each test piece was run under this condition for a period of 10 hours. After completing the run, segments one inch long were cut from the rings and the surface area carefully measured. The bearing alloy and steel backing were then dissolved in dilute acid leaving the sand residue which was washed, dried and weighed. The embeddability factor of the alloy being quoted as the weight of sand in g./sq. cm. of surface area : the results obtained are given in Table IV.

The results clearly reveal the superiority of the tin-base alloy, and although the copper-silver-lead alloy is not up to the same standard, the figure obtained does indicate that it is superior to pure silver. No trouble should be experienced under normal running conditions.

Microstructure

Earlier metallographic examination revealed that there was no evidence of lead segregation in the alloy after casting. A more detailed examination of the structure revealed three distinct phases. Reference to the ternary copper-silver-lead diagram[8] clearly illustrates the mode of solidification. Initial solidification produces the copper-rich phase, followed at a lower temperature by the silver-rich phase, whilst the final solidification is that of the ternary, lead-rich, lead-silver-copper eutectic. Thus the wide solidification range created by the copper- and silver-rich phases, together with suitable cooling technique, should give the desired distribution of the lead-rich phase. The general distribution of this phase is shown in Fig. 6, from which it will be noted that it is quite uniform, and that there is no segregation adjacent to the junction with the steel shell so that there should be no bonding difficulties. Fig. 7, taken at high magnification, reveals quite clearly the three phases present in the alloy.

Conclusions

Laboratory tests have shown that an alloy containing 30% copper, 30% silver and 40% lead can be readily bonded to mild steel using standard casting techniques, and that it does fulfil the major requirements of a bearing alloy. In some instances the properties are equal to, and in others better than, those of some of the present day alloys. The mechanical properties at elevated temperature are better than those of the tin-base alloy, whilst the compressive strength at temperature is equal to that of the 30% lead, copper-lead alloy, and much better than the tin-base alloy. Thus, theoretically, the alloy should be quite suitable for use with high loads at

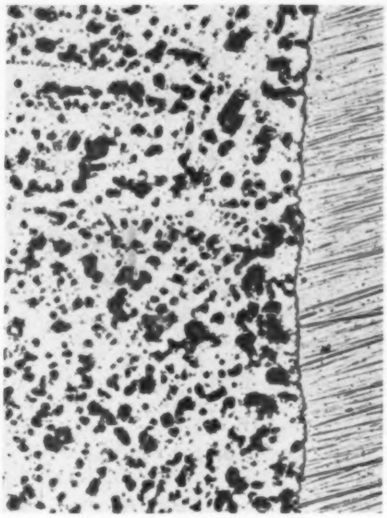
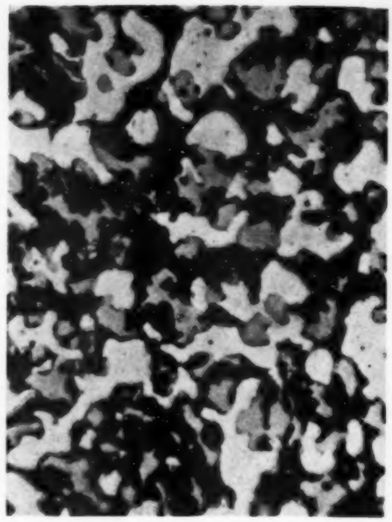


Fig. 6. (left)—General lead distribution in the 30-30-40 copper-silver-lead alloy. ×112

Fig. 7. (right) — Distribution of the copper-, silver- and lead-rich phases in the 30–30–40 alloy. Etched in dilute ammonia solution. ×500



bearing temperatures and should not suffer from fatigue failure. The coefficient of friction is low, owing to the formation of a thin lead film on the surface during running, and so preliminary lead plating of the bearing should be unnecessary.

The resistance to corrosion although not so high as that of the tin-base alloy is good enough to ensure no serious trouble in this direction. The property of accommodating foreign matter is also enough to ensure trouble-free running with any efficient oil filtering system. The coefficient of expansion is not unduly high, so no unusual running clearances would be required.

Although the laboratory tests have shown that the 30% copper, 30% silver, 40% lead alloy does possess most of the desired properties associated with bearing alloys, it is realised that the only satisfactory method of assessing its qualities is to carry out a series of tests on actual bearings under service conditions.

Acknowledgments

The author wishes to thank the directors of the Bristol Aeroplane Co. for permission to publish this paper, and to Mr. P. H. Frith for his interest and helpful criticism.

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Foundrymen Visit Hartlepool Works

AS a result of the kind invitation of the management of Richardsons Westgarth & Co. Ltd., about 70 members of the Newcastle and District Branch of the Institute of British Foundrymen recently visited that Company's works at Hartlepool. Founded originally as marine engineers, this firm has developed considerably and today, in addition to marine engineering, it is well-known for its electrical power plants, general engineering, boiler-making and iron-founding. Although the visit was primarily associated with the foundry the marine and electrical departments were also included.

In both these latter departments there was ample evidence of the excellent work being carried out in these works. Particularly noticeable to foundrymen was the large amount of work involving welding, indicating the great progress in welding techniques. In one instance a completely welded turbine casing was shown. It is evident that further progress in this field will depend to some extent on the energy and progressiveness of the foundry industry. Even in the construction of the turbine rotors, welding plays a very important part.

The marine section proved not less interesting than the electrical, several engines were in various stages of construction and a 6,000 h.p. Doxford engine was almost assembled preparatory to carrying out tests.

As is usual with an old established firm, parts of the works are old and this is true of the ironfoundry, which was probably erected about 70 years ago. It is equipped with four cupolas, three of which are each capable of providing 6 tons of metal per hour. Apart from a toothed wheel moulding machine, which is used for a variety of purposes, no moulding machines are installed. Despite this, however, the quality of work produced compares favourably with that of any other foundry. Particular interest was shown in the method employed for easing a large cylindrical casting after filling the mould, in several intricate cores, and in the running of an unusual stern tube. Many questions were asked and answered by responsible authorities, who had given their time to make the visit interesting.

At the conclusion tea was provided and on behalf of the members taking part, Professor A. Preece, President of the Branch, expressed thanks to the management, various members of the staff who had helped so admirably and to the ladies for looking after the tea. Mr. C. Gresty replied on behalf of the firm.

Carbon in the Engineering and Metallurgical Industries

IV—Refractories, Electrodes and other Metallurgical Uses

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The applications of the carbon and graphite products whose properties and manufacture have been described in previous articles are numerous. Those in the metallurgical field described here are divided into refractories, electrodes, hard metal carbide equipment, and foundry and heat treatment equipment.

HAVING considered in previous articles the production and properties of carbon and graphite products, reference may now be made to a number of applications in the metallurgical field. These may be divided broadly into four groups :—

(*a*) refractories in the heavy industries ;
(*b*) electrodes for electrothermal, electrolytic and welding processes ;
(*c*) equipment for the hard metal carbide industry ; and
(*d*) equipment for the foundry and heat treatment shop.

REFRACTORIES IN HEAVY INDUSTRY

The inert and stable characteristics of carbon make it an almost ideal refractory under certain conditions. It has a very high refractoriness and great mechanical strength, properties which are retained under load at high temperature, while the low coefficient of thermal expansion ensures a stable structure. The thermal conductivity tends to decrease with increase in temperature, thus minimising heat losses from the furnace in which this material is present as an internal refractory lining. Added to these desirable properties, both carbon and graphite have the quality of resisting attack or even " wetting " by molten slags, and have a high resistance to thermal shock.

The most unsatisfactory property is the tendency for oxidation to occur at low temperatures of the order of 350° C. for carbons, and 450–500° C. for electrographites. This means that care must be exercised to see that air, oxygen, water vapour, or even carbon dioxide, does not contact these materials when at temperatures above those stated. At first sight, this may appear to be such a detrimental characteristic that the value of carbon as a refractory may rightly be questioned. However, in certain metallurgical processes furnaces operate with neutral or reducing atmospheres, and under these conditions carbon has established itself as a very suitable refractory in the iron industry, in aluminium reduction furnaces, and in furnaces for the production of calcium carbide and phosphorous.

Iron Making

It is interesting to trace the development of carbon as a refractory in the iron industry where it is used in the lining of blast furnaces. Records indicate[1] that carbon, both in the form of bricks (or blocks) and paste (or ramming) was used as long ago as 1876 in France, whilst the fact that these materials had been used fairly extensively in Germany from as early as 1886, and were continuing to give favourable results, was reported in a paper published in 1912[2].

About 50 years ago, this application was tried out both in England and in the U.S.A., but the results were sufficiently inconsistent that any extensions of the project were shelved. It should, however, be noted that a ferro-alloy furnace with a carbon block hearth sent from Germany was installed in England and ran successfully for a great number of years. About 1914–1918, more interest was shown in the use of mixtures of coke with pitch and tar for blast furnace hearths in this country, especially in the N.E. Coast area, where this method is still largely applied today.

In brief, therefore, there are two schools of thought on the method of applying carbon to blast furnace hearth construction, the one using rammed carbon paste, the other pre-fired bricks or blocks. In the U.S.A., there has grown up a strong belief, which has a great deal of justification, that a hearth made by tamping carbon pastes to give a monolithic structure may be satisfactory if constructed with great care and " blown in " correctly, but it has the inherent weakness of being a large unfired mass which, on being heated in service, must contract due to the expulsion of volatiles, and cracks will develop in consequence. This has often proved to be the case with disastrous results. In contrast, any cracks in a firebrick hearth may fuse over and seal up under the action of temperature and slag attack. Many accounts are cited of attempts to overcome contraction cracks in monolithic carbon hearths by altering the ramming technique, but since the results are so dependent on human judgment it has been the tendency in the U.S.A. to favour the use of manufactured pre-fired carbon bricks, because consistent control of properties may then be expected. Moreover, the contraction in service is reduced to a minimum by virtue of the fact that most of the possible contraction has occurred under controlled conditions during manufacture.

At this point it may be advantageous to digress for a moment to consider why carbon should be used in the blast furnace at all. Up to World War II, it would seem that in the U.K. and U.S.A. firebrick linings of various grades were being used for all parts of the blast furnace, but in Germany about 75% of the blast furnaces had carbon hearths[3]. This appears to have been due to the fact that the quality of firebrick used in the furnace was not good enough for the conditions of service encountered in Europe, mainly as a result of the nature of the burden used. There is little doubt that the low grade phosphoric ores smelted by both German and British

TABLE I[8]—COMPARATIVE PROPERTIES OF 42% Al_2O_3 FIREBRICK AND BRITISH CARBON BRICKS.

Test	Firebrick	Carbon Brick
1. *After Contraction.* Permanent volume shrinkage on reheating in service, especially if to a higher temperature than that used for kilning in manufacture.	1·0% after 2 hr. at 1,500° C., but might become 7–8% after many months of service when vitrified.	0·5% after 2 hr. at 1,500° C. but might be up to 2·5% when heated to 2,000° C.
2. *Thermal Conductivity.* B.th.u./sq. ft./hr./° F./in.	5	17
3. *Effect of Molten and Solidified Iron.* Saturated with carbon.	Firm adhesion.	Not affected
4. *Chemical Attack by Slags, Air, etc.*	Reactions with most slags and with alkalis give products of low melting point. Only extensive water cooling gives economic life.	No reaction with slags, but above 400° C., oxygen, water vapour and CO_2 have an oxidising effect
5. *Crushing Strength (Cold)* (lb./sq. in.)	2,000	10,000
6. *Refractoriness under Load.* (Usually the SiC or fused Al_2O_3 loading pillars fail first when carbon is tested)	Usually fail at 1,525° C. with 50 lb./sq. in.	No effect at 1,500° C. with 2 tons/sq. in. and only slight effect at 1,750° C. with 50 lb./sq. in.
7. *Carbon Monoxide Disintegration.* Howie and Mackenzie[9] have shown that the CO effect on industrial carbon bricks is negligible	Susceptible.	No CO disintegration due to carbon deposition, although with high CO_2 concentration a reaction occurs with carbon at 650° C. to give CO. Blast furnace practice shows that in general the CO_2 concentration in this zone is about 5% (by vol.) and the reaction effect is minimised by nitrogen and CO present. Also the hotter more reactive coke would react preferentially.
8. *Porosity %*	About 23	Similar
9. *Bulk Density or Apparent Specific Gravity.* g./c.c.	About 2·0	About 1·5
10. *Permeability.* c.g.s. units	0·16	0·022
11. *Coefficient of Thermal Expansion.* 20–1,000° C.	0·55%	0·65%
12. *True Specific Gravity*	2·64	1·95

blast furnaces necessitated a highly basic slag, which was very fluid at hearth temperature and acted as an erosive flux on the firebrick linings. It is also believed that European firebricks lacked refractoriness, which, of course, aggravated the condition.

In the U.S.A., however, most furnaces were smelting comparatively rich burdens, much lower in sulphur and phosphorous than those in Europe, and in consequence the slag carried could be more neutral and less erosive on the firebrick hearth, the quality of which is claimed to be superior to the European counterpart.

The solvent power of these fluid basic slags for both British and European firebricks has often led to serious iron breakouts through the hearth jacket, resulting in considerable expense due to loss of production. This point is stressed by Elliot in his excellent report on "Iron Making at Appleby-Frodingham[4]" and led to experiments by his company in the use of carbon, first as ramming and later as bricks, with the object of preventing these breakouts.

The war effort spurred on developments both in this country and in the U.S.A., and we find that by 1946, about twenty-five blast furnaces in the U.S.A. and about half that number in England (of which only two or three employed pre-fired bricks, the others being rammed) had carbon in the hearth and sometimes in the bosh.

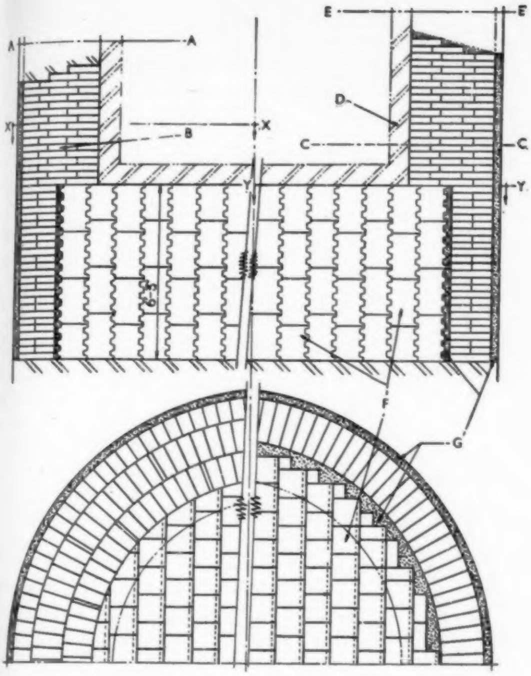
In the post-war years, rapid development of manufacture in carbon blast furnace refractories has occurred on both sides of the Atlantic, but whereas the Americans favour a hearth construction of large beams 2–3 ft. square by some 10–15 ft. long (to reduce the number of joints) laid across the hearth and under the well wall with wide joints of up to 3 in. between beams in which carbon ramming is tamped, smaller blocks and standard firebrick sizes are favoured in this country, because of easier bricklaying. Because of inevitable shrinkage of the unfired jointing material during service (but according to the Americans this is compensated for by the thermal expansion of the carbon beams) the latest idea is to lay the hearth blocks without any mortar whatsoever, and with only the minimum of carbon ramming to make up the shell contour at each end of the rows of blocks.

Since pre-fired carbon does not soften on heating, as does firebrick, any shrinkage "after contraction" in service may allow molten iron to infiltrate between the blocks, and in this way cause the hearth to "float," unless a self-locking design of block is used to render the structure stable. This requirement was met by the development, with which the author was closely associated, of the corrugated carbon block, which is basically a rectangular block with horizontal corrugations on one or two of the vertical faces: where there are two, the corrugated faces are parallel. The standard cross sections for the single corrugated face are 12 in. × 6¾ in. and 6 in. × 6¾ in., and for the "doubles" 12 in. × 12 in. and 12 in. × 6 in. The corrugations measure 5 in. from peak to peak and 1½ in. in depth so that, even if the whole of the contraction of a 22 ft. hearth occurred in one spot, the interlocking would not be freed. There are two standard heights of block, 15 in. and 20 in., so that a stable interlocked hearth structure, in both horizontal and vertical planes, can be obtained. At the same time, the weakness of a straight through joint in the horizontal plane is removed by a base of alternate 15 in. and 20 in. blocks. Any penetration of molten iron downwards through the lengthy, staggered vertical joints will soon stop due to freezing, the thermal conductivity of the carbon blocks being more that three times that of normal firebrick.

This research work, carried out jointly by the carbon brick makers and a well-known iron and steel company, has led to the adoption, first of carbon corrugated blocks as a hearth lining, and later of brick shapes for lining the bosh and parts of the stack susceptible to carbon monoxide disintegration. Results of these earlier trials culminated in the building of an "all-carbon" furnace in this country in 1949—the first in the world.

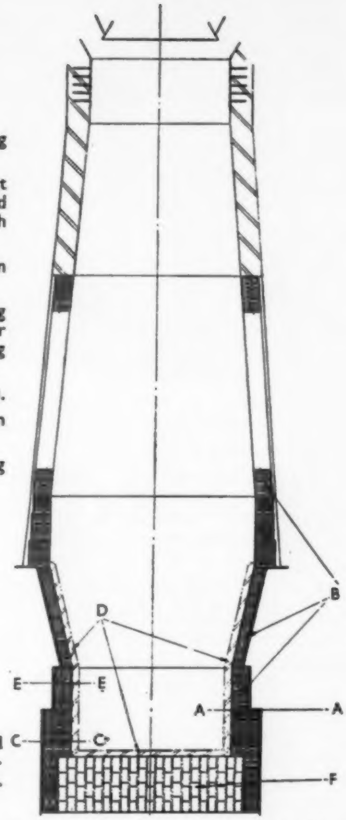
Full details of these earlier trials and results to date may be found in the technical literature[5, 6]. German carbon hearth lined blast furnaces have been reported to have produced over 2 million tons of iron per furnace on the same hearth[3].

Fig. 1[7] shows a typical hearth bottom and wall construction using corrugated carbon hearth blocks and normal wall shapes, whilst Fig. 2[7] shows the scheme



Part section on XX — Part section on YY

Fig. 1.—Typical hearth bottom and wall construction using corrugated carbon hearth blocks and normal wall shapes.



- AA Centre line of slag notch.
- B Standard carbon blast furnace shapes, jointed and bedded with special mortar.
- CC Centre line of iron notch.
- D 9 in. thick loose lining of firebrick for protection during blowing-in only.
- EE Centre line of tuyeres.
- F Corrugated carbon hearth blocks.
- G Carbon ramming material.

Fig. 2.–Scheme adopted for lining the first "all-carbon" blast furnace.

adopted for lining the first "all-carbon" blast furnace almost up to the throat armouring. Table I shows the superiority, in most respects, of British carbon bricks suitable for blast furnace use, when compared with good quality aluminous firebrick used for a similar purpose.

Another use of carbon bricks in the iron industry lies in the construction of iron runner channels. The advantages include the elimination of the silica pick-up which occurs with the normal sand-lined trough, and the fact that the runner retains its shape between casts, with little attention apart from a necessary wash over with a clay-graphite slurry after each cast to prevent atmospheric oxidation.

The main drawback to the increased use of carbon bricks for these applications has been the initial outlay, since, in general, the cost per ton of suitable firebrick is about ¼ that of carbon bricks. A greater number of standard shapes of the latter are obtained for a given weight, however, due to a favourable difference in the respective specific gravities of the two materials.

Ferro-Alloy Furnaces

Mention must now be made of the large tonnage of carbon used annually, in the form of ramming or pre-fired bricks, for lining the hearth and walls of ferro-alloy units of both the blast furnace and electric furnace types, including the "electric blast furnace" used for smelting iron in Scandinavia and Italy. Calcium carbide furnaces, magnesium oxide reduction furnaces, and electric furnaces used for producing phosphorous, all have carbon linings and may vary in size from 6 ft. to 25 ft. in diameter.

The carbon lining for electrolytic aluminium production may be made with pre-fired bricks carefully ground and laid (within the steel heat insulated furnace shell) around the conductor bars used to convey current to the insulated carbon lining, which also acts as the cell cathode ; or it may be made from carbon paste carefully tamped when warm into a sound monolithic hearth structure, with the conductor bars embedded in the mass.

In both cases a high grade carbon mixture is used, containing calcined anthracite coal, calcined petroleum coke flour, pitch and tar. This should give a product which suffers from a minimum contraction shrinkage on heating in service to about 1,000° C.

Although a rammed lining is considered much less costly than one constructed from pre-fired bricks, much depends on the skill of the tampers as to whether the lining will give an economic life or will soon develop shrinkage cracks and allow metal seepage. Furthermore, the labour problem is difficult since, during tamping, tar and pitch fumes are evolved which are unpleasant and may be injurious to the workmen.

ELECTRODE APPLICATIONS

Electrode applications in three important metallurgical fields will be considered, viz., electro-thermal smelting or melting in the ferrous and non-ferrous industries ; electrolytic production of non-ferrous metals ; and carbon arc welding.

Furnace Electrodes

For arc furnace smelting, both amorphous carbon and graphite pre-formed electrodes and Soderberg paste electrodes are widely used. The particular application

of any one type to a furnace process is dependent on several physical properties which influence economic considerations. The comparative values for several relevant properties relating to pre-formed electrodes are shown in Table II.

In the U.K. and on the Continent, the raw materials used are mainly ground metallurgical coke, petroleum coke, pitch and tar, and manufacture is almost entirely by extrusion. In the U.S.A. petroleum coke is preferred to metallurgical coke because of the greater degree of purity obtained in the resulting product.

The ash from carbon electrodes may be as high as 7%, and contains varying proportions of SiO_2, Fe_2O_3, Al_2O_3, SiC, whereas electrographitised electrodes have only up to 1% ash, with SiO_2 representing about one-sixth of this and the balance made up of traces of other metal oxides. Because of this feature, the electrographitised variety is more suitable for electrolytic processes as the contamination is reduced, whereas carbon electrodes will suffice for iron and steel production (with reservations). The greater disintegration rate of carbon electrodes renders them less suitable for the making of low carbon steels, where carbon pick-up from the electrodes must be avoided.

The other considerations which decide the type of electrode used in arc furnaces are mainly constructional and operational, in that, for a given electrical input to a furnace, a certain cross sectional area of electrode is necessary, and this will give the alternatives of using either a small diameter graphite electrode or a larger size of carbon electrode. With multi-electrode arc furnaces, structional weakness of the roof would result from the use of a number of large holes to accommodate carbon electrodes, so graphite would be employed, but against this consideration, the larger carbon electrodes are mechanically stronger and also help to shield the roof from radiated heat produced at the arc. A compromise is usual and, in general, furnaces up to about 20 tons capacity use carbon, whilst above that size graphite is used. With the tendency towards greater furnace sizes and outputs, the consumption of graphite electrodes now outweighs that of carbon in the U.S. steel industry.

The relative application of carbon and graphite electrodes with their consumption per 1,000 lb. of product (for American practice) is shown in Table III.

Electrodes for Electrolytic Processes

In the electrolytic processes for the production of aluminium, magnesium, calcium, sodium and beryllium, the consumption of electrode material is very appreciable and is of the order of 0·6–0·85 lb./lb. of aluminium and 0·2–0·3 lb./lb. of magnesium. Generally speaking, low ash (less than 1%) electrographitic electrodes, made from petroleum coke or purified anthracite, are desirable, and their shape, which is often in the form of blocks up to 15 in. square × 18–24 in. long, placed together in rows (European practice), lends itself to manufacture by either pressing or extrusion. American aluminium production plants appear to use the normal cylindrical shapes.

The Soderberg type of self-baking electrode is becoming increasingly popular for both ferrous and non-ferrous smelting furnaces. This type of electrode, which was developed in Norway about 30 years ago, is in fact a continuous, jointless electrode, which is built, baked and renewed in the furnace in which it is used. In Europe, and Scandinavia in particular, this type of electrode is finding a wide application for aluminium reduction furnaces[9, 10], for the smelting of copper matte (Norway), for calcium carbide production[11], and in pig iron, ferro-alloy[12] and steel furnaces; in all cases supplanting the standard pre-fired electrodes. The mixture used varies slightly with the application, but is in general, similar to that which would be used for standard electrodes for a similar application. This paste, warmed to about 130° C., is fed into a sheet metal casing, which is cylindrical or rectangular in section according to the shape of electrode required. The sheet metal is mild steel for use in the ferrous industries and in calcium carbide production, whilst for aluminium extraction an aluminium casing is used.

TABLE II.—COMPARISON OF PROPERTIES FOR CARBON AND GRAPHITE ELECTRODES.

	Amorphous Carbon	Electro-graphite
Specific Resistance (ohms/in.^{3})	0·00080	0·00032
Ratio of Electrical Conductivities	1	4
Current Carrying Capacity (amp./sq. in.)	40–50	120–180
Temperature of Oxidation in Air (° C.)	450–500	600–650
Tensile strength (lb./sq. in.)	1200	800
Ratio of Cost	1	2–2·5
Max. Size Available (in the U.S.A.)	40 in. diam × 110 in. long.	20 in. diam. × 72 in. long.

Within the casing are a number of radial ribs which support the paste until it becomes baked on descending into the hot zone of the furnace; they also function as current distributing rods. Holes in the casing provide an exit for gases evolved during baking.

The electrode is fed continuously into the furnace by "Wisdom brakes" which are mild steel strips tack-welded to the casing at intervals and friction gripped by guides above the furnace. As a portion of electrode becomes consumed a new 4–6 ft. length of casing is welded on to the top of the existing electrode. The maximum sizes in service are 45 in. diameter for the ferrous industry and 15 ft. × 4 ft. for aluminium.

Advantages claimed for this electrode (where one may replace several pre-fired electrodes) are: saving in cost since there are no "butt" ends and manufacture is done on site; low consumption (0·45 lb./lb. aluminium); and high current efficiency (90%).

Welding Electrodes

Carbon welding rods, $\frac{1}{12}$–1 in. in diameter × 12–36 in. in length and made from graphitic carbon mixtures and electrographitic material, are widely used for joining light gauge metal parts[13]. A carbon arc struck between the welding rod and the work is said to be more stable and hotter than a metallic arc, and generates its own protective atmosphere around the weld. A filler rod of similar material to the work being welded is fed into the arc and the molten drops form the weld.

THE HARD METAL CARBIDE INDUSTRY

The hard metal carbide industry was started in Germany just prior to the 1914–1918 war and the

TABLE III.—CONSUMPTION OF CARBON AND GRAPHITE ELECTRODES IN THE FERROUS AND NON-FERROUS INDUSTRIES (U.S.A.—lb./1,000 lb. of product).

Application	Carbon	Graphite
Non-Ferrous Metals	—	1·25–5
Iron Castings	—	1·5–7
Steel Castings	4·5–10	2·25–5
Steel Ingots	8·5–15	5–10
Ferrosilicon (50%)	22–33	—
Ferromanganese (80%)	30–35	—
Ferrochromium	40–50	—
Pig Iron Production (electric furnace)	9–13·5	—

tungsten carbide tools and drawing dies were later sold in England under the trade name of "Widia" metal. American companies in 1925 bought the rights to work the German patents, and in the last 25 years progress in the hard metal carbide industry both in England and abroad has been rapid. In the following rèsumè[14,15] of the processes commonly practised, it will be seen that carbon and graphite have many functions which are not easily replaceable by any other material.

Tungsten powder (of grain size about 1 micron), produced from the reduction of tungstic oxide by hydrogen at 900° C., is thoroughly mixed in a ball mill with the calculated weight of lampblack (–300 mesh) to give a product containing about 6% carbon. The mixed powders may then be heated to about 1,600° C. in a hydrogen atmosphere. Graphite boats fitted with lids are used for containing the powder, and heating is carried out in carbon (or graphite) resistor tube furnaces (as shown in Fig. 3) or by high-frequency induction in a large machined graphite crucible.[16]

The tungsten carbide powder produced is next mixed with 3–20% by weight of fine cobalt powder with additions of such other metal carbide powders (titanium, tantalum or boron carbides) as may be required for special applications, and ball milled thoroughly to ensure close proximity of each carbide particle with a cobalt particle—the addition of small quantities of distilled water or carbon tetra-chloride helps in this respect.

The ground product is dried and sieved to pass 200 mesh, and is now ready for fabrication into pieces for tool tips, rock or coal drill bit inserts, sand blasting nozzles, drawing dies, etc., by one of three processes: cold pressing and sintering, hot pressing or casting.

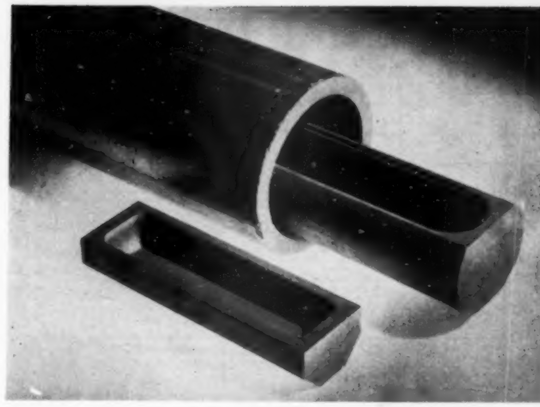
Cold Pressing and Sintering

With cold pressing, the carbide-cobalt powder mixture is compressed (5–20 tons/sq. in.) in appropriate steel moulds machined 30–40% oversize internally on all dimensions—this is to allow for contraction during the sintering processes. The compact is heated to 700–1,000° C. (pre-sintered) in an atmosphere of hydrogen or cracked ammonia whilst contained in a graphite boat, with graphite packing powder within it to protect the compact from decarburisation. After pre-sintering any machining may be carried out with allowance for 20% volume contraction in the final sintering process.

This consists of an almost identical set-up with boats, furnace and atmosphere, but the temperature employed is between 1,400 and 1,600° C. After about an hour at temperature, the sintered product is pushed through to a cooling chamber attached to the furnace. A final grinding to correct dimensions, followed by polishing in the case of drawing dies, should be all that is necessary.

Hot Pressing

Hot pressing is a more recent process and combines a simultaneous pressing and heating. This is eminently suitable for simple but large pieces which would require large and costly cold presses, dies and sintering furnaces. A pre-determined weight of carbide-cobalt powder is fed into accurately machined moulds of graphitic carbon (in this case the mould is machined to final required dimensions) sometimes containing graphite cores and compressed by a vertical carbon plunger at a pressure of 1–5 tons/sq. in. Simultaneous with the application of pressure, heating of the mould to 1,200–1,400° C. (either by a high frequency coil surrounding the mould,



Courtesy of The Morgan Crucible Co., Ltd.

Fig. 3.—Carbon boats and furnace tube for high temperature work.

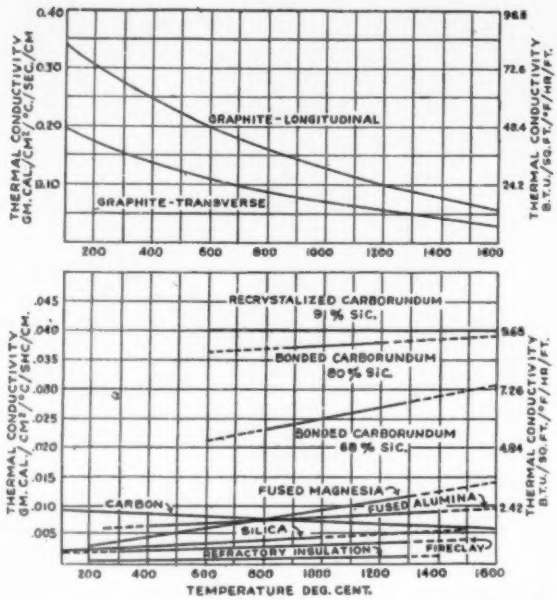
or by the resistance of the mould and powder to the passage of a heavy current) is carried out for 1–30 minutes depending on the size of the compact. No protective atmosphere is necessary. After the operation, the cold mould is dismantled and the compact extracted and sand blasted to remove any adhering carbon.

Casting

The casting of metal carbides is not common practice in the U.K., but is in favour on the Continent for extremely hard inserts used on rock drill crowns, and for sand blasting nozzles. In general, a powder mixture of tungsten, titanium, tantalum and chromium carbides, with about 3–6% cobalt, nickel or iron as a binder, is contained in a graphite boat which serves as a crucible. Attached to the boat, and connecting with its interior, is a machined graphite mould into which the molten carbide alloy will be cast. The whole assembly is usually heated in a horizontal carbon tube resistor furnace, with a dry hydrogen atmosphere, to a temperature in the region of 3,000° C. by passing a heavy current of 2,000–3,000 amps at 10–15 volts through the tube. Casting is accomplished, either by tilting the furnace to allow the molten alloy to flow under gravity into the mould, or centrifugally by spinning the furnace in a horizontal plane.[17] The cast material is removed from its mould (after cooling immersed in carbon granules) in a similar manner to that described under hot pressing.

It has been shown that carbon in its many forms plays a very important part in this vital industry and although, for certain stages of the processes, furnace tubes of fused alumina wound with molybdenum wire may be used as an alternative to carbon, no alternative exists for tubes in the casting process, or for the boat and mould materials necessary to protect the carbide pieces from hydrogen decarburisation.

Carbon and graphite tubes are made in a variety of sizes up to 10 in bore, with wall thickness up to $\frac{5}{8}$ in., and in lengths up to 6–10 ft. Operating conditions decide which grades are suitable, particularly with reference to specific resistance. Sintering boats and casting moulds should be easily machinable, close textured graphites, and for hot pressing moulds, cores and plungers, machinability, surface finish and compressive strength are important factors. Carbon granules of various mesh sizes are often used as a thermal insulator packing in carbon tube furnaces.



Courtesy of Van Nostrand

Fig. 4.—Thermal conductivity of carbon and other refractories.*

FOUNDRY AND HEAT TREATMENT APPLICATIONS

Apart from the well-known use of graphite as a mould facing or dressing, other foundry applications are in the development stage and some will undoubtedly become standard practice.

In the U.S.A., in particular, large graphite ingot moulds have been claimed[18] to give up to 538 casts, each of about 2 cwts., of both carbon and alloy steels before scrapping due to erosion. The moulds were in two identical halves (giving a "big end up" ingot) and had a replaceable bottom plug of similar material. It is claimed that no "stickers" were experienced, thus giving faster stripping; no mould washing was necessary; and, owing to the greater conductivity of graphite compared with cast iron (about twice as great in the range 750–1,000° F.) a finer grain structure with less segregation resulted.

In this country, successful trials have been carried out using machined graphite moulds for casting ingots of Nimonic alloy and nickel-chrome resistance alloys, and for simple castings in aluminium alloys (800 casts per mould were obtained).

Interest has been shown, particularly in the steel industry, in the use of graphite (and plumbago) ingot stools and plug inserts, especially for ingots of high quality tool steels. One reason for this is tha' fireclay plugs, which usually fracture at each cast, tend to give silica pick up in the form of inclusions found at the base of the ingot. Furthermore, the thermal conductivity of fireclay being low results in a coarse grain structure at the base of the ingot which frequently leads to cracking on rolling. The high rate of heat transfer of graphite (almost equal to brass) has been found to give a refined grain structure and, because of their high thermal spalling resistance, these plugs may be used several times. The erosion rate of graphite mould stools compares quite favourably with the more usual cast iron. Comparative values of thermal conductivity for various metallic and non-metallic materials are set out in Table IV, and a comparison with other refractories is shown in Fig. 4.

Another suggested use[19] for graphite moulds has been in the centrifugal casting of non-ferrous alloys, but some trials in this country have shown them to have an uneconomic life.

Tests in the U.S.A.[20] have shown that if graphite rods are inserted in the open risers of steel castings, a smaller riser may be used since solution of the graphite in the steel gives increased fluidity, and the heat generated by oxidation of the graphite rod assists this. The carbon pick-up by the casting is said to be confined to the riser volume and does not extend into the casting.

The magnet industry has had some measure of success in the use of graphite rods as cores in the casting of magnets. The application has also been tried in the non-ferrous field for casting phosphor-bronze "sticks" for bearings, but results have been inconclusive.

As a core material, graphite has attractive features in that long straight lengths of accurate section are readily available, and are much more robust than sand cores. Furthermore, their smooth exterior gives a good finish to the bore of the casting and may dispense with further machining.

Graphite cores must, however, possess the desirable properties found in sand cores, viz., to remain solid long enough for the molten metal to solidify, and yet be sufficiently friable to allow easy removal. It is also necessary that the core should "give" during the freezing of the metal to prevent hot tears, and that no chemical reaction should occur between metal and core which would give rise to gas evolution.

Although some progress has been made in this application, much has still to be accomplished in obtaining the correct constitution for the core material which will fulfil all the above requirements. Only then may the more costly graphite core replace the present standard practice.

In certain heat treatment processes, graphite finds limited application but the following examples are worthy of mention.

Decarburisation of steel, particularly high speed steel, during heat treatment may be minimised if carried out in a neutral atmosphere generated by partial burning of a graphite muffle in a limited air supply. Watson[21] shows this method to be very effective, particularly for temperatures in excess of 930° C., below which the CO_2/CO ratio is high enough to cause decarburisation. These slow burning muffles are termed "diamond blocks."

A similar principle is applied in the furnace brazing of small electrical contact screws using brass or silver

TABLE IV.—AVERAGE THERMAL CONDUCTIVITIES FOR VARIOUS MATERIALS.

Materials	Conductivities* B.Th.U./sq. ft./° F./hr./ft.
Copper	224
Red Brass	93
Electrographite	75
Cast Iron	30–35
Carbon	3
Firebrick	0·7

* All tests at room temperature.

* It will be appreciated that variations in thermal conductivity of carbon and graphite products may arise from variations in constituents and methods of manufacture.

solder. The screw, solder and contact tip are assembled in large numbers and each assembly is carried in individual holes machined in graphite blocks. The blocks with their contents pass on a continuous belt at a slow rate through the correct temperature zone of an electric furnace containing a protective atmosphere. This atmosphere, assisted by the close proximity of the graphite, prevents oxidation of the assembly pieces, and thus allows brazing without the necessity for a flux.

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December Diary of Meetings

1st

Institute of Metals—Oxford Local Section. "Welding," by DR. W. I. PUMPHREY. Oak Room, Cadena Café, Cornmarket Street, Oxford. 7 p.m.

Institute of Metals—South Wales Local Section. "Metallurgical Research in the Electrical Industry," by DR. I. JENKINS. University College, Metallurgy Department, Singleton Park, Swansea. 6.45 p.m.

Institution of Engineering Inspection. "Engineers at War" Part 1—'Bridging and Communications.' By LT.-COL. W. H. HOOPER. Grand Hotel, Broad Street, Bristol. 7.30 p.m.

Institution of Engineering Inspection. "Modern Developments of Mining Machinery," by H. ENTWISTLE AND D. CREETH. Room A5, Coventry Technical College. 7.30 p.m.

Institution of Engineers and Shipbuilders in Scotland. "A Century of Coaster Design and Operation," by J. C. ROBERTSON AND H. H. HAGAN, O.B.E. 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

2nd

Institute of British Foundrymen—London Branch. "Bell Founding," by H. M. HOWARD. Joint Meeting with the London Local Section, The Institute of Metals. Waldorf Hotel, London, W.C.2. 7.30 p.m.

Institute of Metals—London Local Section. "Bell Founding," by H. HOWARD. Joint Meeting with the London Branch, Institute of British Foundrymen. Waldorf Hotel, London, W.C.2. 7.30 p.m.

Institution of Engineering Inspection. "Metallurgical Control of Drop Forgings," by K. J. ABBOT. Room 3, Birmingham Chamber of Commerce, New Street, Birmingham. 7.30 p.m.

3rd

Institute of British Foundrymen—Southampton Section. Films: "Casting a Cylinder Block" and "Casting of Hiduminium Alloys." Southampton Technical College, St. Mary Street, Southampton. 7 p.m.

Institution of Engineering Inspection. "The Work of the Printing, Packaging and Allied Trades Research Association," by DR. G. MACDOUGALL. Royal Society of Arts, John Adam Street, Adelphi, London, W.C.1. 6 p.m.

Leeds Metallurgical Society. "Some Modern Copper-Base Alloys," by DR. E. VOCE. Chemistry Dept., University, Leeds, 2. 7.15 p.m.

4th

Institution of Mechanical Engineers. "Comparative High Temperature Properties of British and American Steels," by W. E. BARDGETT AND DR. C. L. CLARK; and "A Critical Examination of Procedures Used in Britain and the United States to Determine Creep Stresses for the Design of Power Plant for Long Life at High Temperatures," by DR. R. W. BAILEY, F.R.S. Storey's Gate, St. James's Park, London, S.W.1. 5.30 p.m.

8th

East Midlands Metallurgical Society. "Powder Metallurgy," by DR. L. HARRISON. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7.30 p.m.

Institute of British Foundrymen—Slough Section. "Sands," by A. P. LOVAT. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Institution of Mechanical Engineers. "Functions of Materials in Bearing Operation," by P. P. LOVE, P. G. FORRESTER AND A. E. BURKE. Storey's Gate, St. James's Park, London, S.W.1. 5.30 p.m.

Institution of Works Managers. "Industrial Relations." by F. V. EVERARD. Grand Hotel, Birmingham. 7 p.m.

9th

East Midlands Branch. Incorporated Plant Engineers. "The Failure of Metals," by PROFESSOR J. A. POPE. Demonstration Theatre, East Midlands Gas Board Showrooms, Parliament Street, Nottingham. 7 p.m.

Institution of Engineering Inspection. Films presented by Imperial Chemical Industries, Ltd., (Dyestuffs Division). Leeds Church Institute, Albion Place, Leeds. 7.30 p.m.

Manchester Metallurgical Society. Discussion on "Temperature Measurement and Control." Lecture Room, Central Library, Manchester. 6.30 p.m.

Society of Chemical Industry Corrosion Group. Joint Meeting with The Oil and Colour Chemists Association. "Electrical Measurements in the Study of Paint Coatings on Metal," by D. M. BRASHER, A. H. KINGSBURY AND F. WORMWELL; "Mechanism of Protection by Paints," with special reference to the action of Basic Pigments," by J. E. O. MAYNE AND D. VAN ROOYEN. Chemical Society, Burlington House, Piccadilly, London, W.1. 6.30 p.m.

10th

Liverpool Metallurgical Society. "Bearings and Bearing Alloys," by P. T. HOLLIGAN. Liverpool Engineering Society, The Temple, Dale Street, Liverpool. 7 p.m.

11th

North-East Metallurgical Society. "Steels and other Alloys for High Temperature Applications," by DR. J. M. ROBERTSON. Cleveland Scientific and Technical Institute, Middlesborough. 7.15 p.m.

14th

Institute of Metals—Scottish Local Section. "Corrosion, Particularly under Marine Conditions," by DR. P. T. GILBERT. Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

Institution of Engineering Inspection. "Radiography in Engineering," by T. G. SMITH. Compton Grange, Compton Road, Wolverhampton. 7.30 p.m.

15th

Institution of Engineers and Shipbuilders in Scotland. "Some Factors in the Design and Lubrication of Journal Bearings," by PROF. A. S. T. THOMSON, PROF. A. W. SCOTT, W. FERGUSON AND H. L. MCBROOM. 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

18th

West of Scotland Iron and Steel Institute. Open Hearth Forum, opened by J. W. TODD, J. A. KILBY, A. I. AITKEN AND J. H. GLOAG. 39, Elmbank Crescent, Glasgow, C.2. 6.45 p.m.

30th

Institute of Metals—Birmingham Local Section. "Metals in Tele-Communications," by C. E. RICHARDS. James Watt Memorial Institute, Great Charles Street, Birmingham. 6.30 p.m.

The Pametrada Research Station

Material Investigations in Progress

Closely linked with the engineering developments in the steam and gas turbine fields are the improved materials of construction which have made possible the adoption of the higher operating temperatures essential to greater thermal efficiencies. Reference is made to some aspects of the investigations being undertaken at PAMETRADA *in this connection.*

THE Parsons and Marine Engineering Turbine Research and Development Association (universally known by its initials PAMETRADA) came into being in May, 1944, when shipbuilding and marine engineering firms manufacturing marine turbines in the British Isles collaborated in the establishment of a marine steam turbine research and testing station. The present Director, Dr. T. W. F. Brown, was appointed in September, 1944 as the first full-time member of the staff. On December 31, 1945, the Association was incorporated as a limited company, and since June, 1946 it has received an annual grant from the Department of Scientific and Industrial Research, with which it maintains close contact while remaining fully autonomous. The pace at which PAMETRADA has grown is indicated by the rapid expansion in staff, which has increased from 15 in 1945 to 227 at the end of 1951, and 250 at the end of 1952.

PAMETRADA's functions, briefly, are to initiate and carry out research for the improvement and development of steam and gas turbines, with all their associated and auxiliary equipment for marine propulsion; to carry out full-scale tests of turbine installations; to set up standards of fit and finish required in the principal components of turbine machinery; and to advise member firms in all matters associated with the design and layout of marine turbines and reduction gear. PAMETRADA acts as consultant to the marine engineering industry and designs are developed in conjunction with member firms, who are responsible for all contractual relations between their clients and themselves.

In carrying out these duties, PAMETRADA has acquired a vast amount of knowledge, which has been of the utmost value to its member firms and to marine engineering as a whole. The developments arising from its work are covered by British and foreign patents. That PAMETRADA's work is attracting the attention of European countries and the Dominions is shown by the growing number of enquiries received from marine engineering firms in various countries for licences to build turbines to the Association's designs. So far licences have been granted to five companies in Holland and one in Canada. All income accruing from this source is ploughed back into research, for the Association is strictly non-profit-making.

Naturally, many of the activities of the Association concern the mechanical engineer more closely than they do the metallurgist, but the latter has played, and is continuing to play, an important part in the advance towards higher operating temperatures of prime movers. In the following brief account of the work of the Association, therefore, attention will be concentrated on those aspects having a metallurgical interest.

Material Problems of the Gas Turbine

The 3,500 s.h.p. marine gas turbine developed by PAMETRADA in 1946 was designed for a working temperature of 1,250° F. (670° C.) in order to give a working life to all components of between 10,000 and 100,000 hours. Further development work in the gas turbine field is centred on the use of higher gas temperatures—i.e., from 1,000° C. upwards—because higher temperatures mean higher efficiency and a smaller size of engine for a given power. The limiting factor is the temperature which the turbine and, in particular, the blading can withstand. Research is therefore being directed towards the development of better materials and better methods of construction.

If really high temperatures — i.e., 1,000° C. and upwards—are to be used, it will almost certainly be necessary to resort to some form of cooling, so that highly stressed components such as the rotor and blading can be kept at temperatures at which they can operate for many thousands of hours. The development of cooled gas turbines has the further advantage that it may be possible to use the less expensive low alloy steels, which are not only easier to fabricate, but do not suffer from the disadvantages of highly alloyed austenitic materials, notably a high coefficient of expansion and a low thermal conductivity.

A turbine consists of alternate rows of fixed and moving blades. The latter are highly stressed because of their rotary motion and it is therefore proposed to cool them. This will be done by providing cavities inside them which will be filled with liquid. Due to the extremely high speed of rotation of the blade, the forces of gravity, and hence the forces of convection, will be multiplied many thousands of times, the effect being that the circulation of the liquid in the cavity will be very rapid and the rate of cooling will be extremely high.

The fixed blades cannot be cooled by the same method but are less highly stressed. Since the temperature in view is 2,200° F., which is much higher than any form of steel could withstand, it is proposed to make the fixed blades of refractory materials, Refractories fully capable of withstanding such temperatures are available, the limiting factor in this case being ability to withstand thermal shock.

Refractories with high thermal shock resistance and other special properties have been developed by the Morgan Crucible Co., Ltd., under a research contract from PAMETRADA to which the Admiralty also contribute.

The Association is actively engaged in the manufacture of an experimental single-stage turbine with refractory fixed blades and liquid-cooled moving blades. The results of previous tests indicate that the difficulties associated with the refractory materials can be satisfactorily overcome.

A further approach to the blade cooling problem involves the use of porous metal. There is enough information available to show that the effusion of a cool fluid through a porous wall has great possibilities as a method of cooling objects exposed to high temperature surroundings, but little of this information relates to

Gas turbine stator blades after running on residual fuel plus an additive (magnesium acetate).

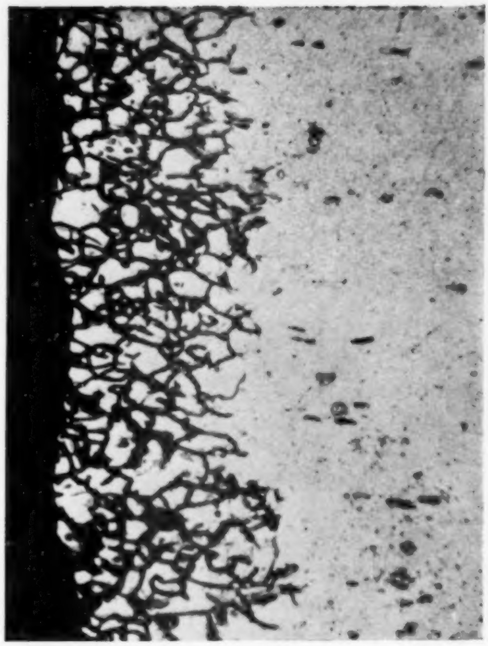
turbine blades. The immediate aim of the work in progress at Pametrada is to obtain design data for effusion-cooled gas turbine blades. The hot gases from a combustion chamber are passed over a cascade of blades, one of which has porous walls to which cooling air is supplied via the blade root.

There are a number of gas turbine applications where resistance to oxidation at elevated temperatures is of more importance than creep strength, e.g., outer casings of combustion chambers, certain parts of ducting etc., and conservation of strategic alloys can be effected by upgrading mild steel by the use of protective coatings. Tests have been carried out on aluminised, calorised and ceramic-coated mild steel. The combustion chambers of the 3,500 s.h.p. marine gas turbine are made with heat resistant steel flame tubes of the 25% chromium, 20% nickel type, with a mild steel outer casing which is aluminised. No troubles have been experienced with the flame tubes of these combustion chambers, which are capable of operating at metal temperatures up to 1,050°C. without excessive scaling.

Residual Oils as Fuel

Running on distillate fuels the Pametrada gas turbine has given very satisfactory results. To compete with diesels, however, marine gas turbines must be capable of using heavy residual oils, which are the cheapest forms of fuel oil. There is no difficulty in burning these oils, but the products of combustion present two major problems.

Left in the gas stream are small particles of impurities which are incombustible. These particles tend to be sticky and may be completely molten when they enter the turbine, so that they are apt to adhere to the blades of the turbine and block up the passages between them. The second problem is caused by the presence of vanadium, which is a constituent of nearly all residual oils. The products of combustion usually include vanadium pentoxide which is molten at temperatures of the order of 650° C. Vanadium pentoxide when molten is highly corrosive and will attack all commercially available heat resisting alloys; in fact, no metal appears to be completely immune. The rate of attack is very high and increases progressively with temperature.



Special chromium-nickel austenitic steel after 50 hours at 820° C. in contact with $V_2O_5 + 10\%$ Na_2SO_4. ×250

Pametrada and other research organisations are endeavouring to solve the corrosion and fouling problems, the following being the main lines of attack :—

(*a*) attempts to remove the incombustible matter from the oil before burning ;

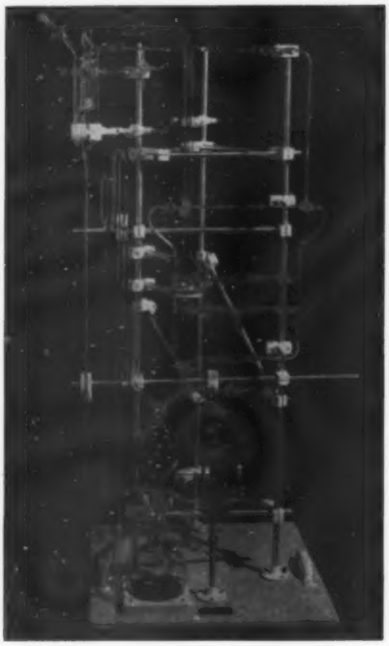
(*b*) the use of fuel oil additives which change the ash to a non-sticky form ;

(*c*) attempts to remove the ash from the gas stream before it reaches the turbine.

The chemical section at Pametrada has attempted to remove the vanadium from residual fuels. Centrifuging was tried, not very hopefully, and proved ineffective. Attention was then directed to the possibility of leaching out the vanadium with inorganic acids and bases. Attempts were made with dilute sulphuric acid, caustic soda, dilute phosphoric acid, and 95% sulphuric acid. The only effective agent investigated was 95% sulphuric acid, which also removed a high proportion of the other oil constituents. Solvent extraction was then attempted with various organic solvents. Alcohol and acetone were ineffective ; with phenol and aniline up to 50% of the total vanadium present could be removed, but no means of improving this figure could be found.

Various compounds have been added to the fuel, or to the gas stream at the combustion chamber, in attempts to render the ash non-sticking and non-corrosive. A certain amount of success has been achieved with additives of the basic metal oxide type ; e.g., zinc oxide, calcium oxide, magnesium oxide, etc. These additives reduce corrosion to a considerable extent, but they have not provided a solution to the fouling problem, which is being attacked on other lines.

Considerable effort has been put into the attack on these particular problems, and, in spite of the difficulties encountered, the Association is confident that before long they will be solved.



Apparatus for analysing gases in steam.

High Temperature Steam Turbines

There are indications that in due course the gas turbine will supplant the steam turbine, but this will not be for many years. The flexibility and adaptability of the steam turbine have not yet been exploited to the full and research in this field is being very actively undertaken by PAMETRADA. The trend of development is in the direction of higher pressures and temperatures, and the extent to which steam temperatures can be raised seems to depend mainly on the availability of suitable materials.

A point will eventually be reached when it will be necessary to consider the use of austenitic steels for such components as blading and superheater steam pipes. This will lead to the problem of welding the austenitic steel tubes to one another and to the ferritic steel piping which occurs outside the superheater. In order to provide experience with high temperature steam in conjunction with high pressure, an experimental unit known as " Pamela " has been designed. Particular attention will be paid to the performance of the special materials used. " Pamela " is a 6-stage impulse turbine, which represents the high pressure cylinder of a three-cylinder turbine developing about 3,000 h.p. The maximum conditions are 1,100° F. and 1,100 lb./sq. in.

Materials for marine gas turbine compressor and steam turbine blades must have a high resistance to chloride corrosion, and, in order to ensure that the most suitable materials are selected, an intermittent salt spray apparatus is being used to determine the relative resistance of various alloys to this type of attack. Specimens are subjected to repeated cycles of spraying and drying, using spray solution of 3% sodium chloride and sea water, and experiments at present in progress are designed to determine the effect of various surface finishes and different heat treatments on stainless iron.

Another type of corrosion problem occurs in connection with steam turbines. In certain ships the L.P. cylinder casings have become severely corroded. This condition occurs in the wet region of the turbine and is thought to be associated with the action of dissolved gases from the steam. PAMETRADA's chemical section has been asked to determine the quantities of foreign gases in a steam turbine cycle and also their composition. For this purpose a special sampling apparatus has been developed, which condenses a sample of steam, boils the concentrate, and enables the gas sample to be collected in a tiny glass vessel. The sample is completely immersed in paraffin wax, which is allowed to solidify, and brought back to the laboratory for analysis.

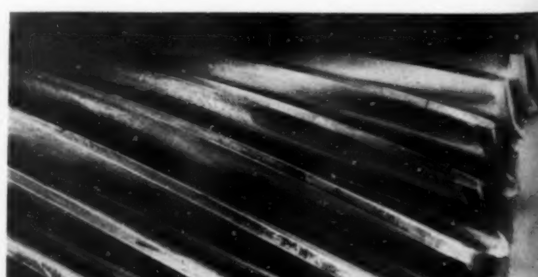
As small samples of gas (sometimes of the order of 0·2 ml. at ordinary pressures) have to be examined, the analysis is carried out at reduced pressure to increase the gas volume, and the apparatus illustrated is based on one first suggested by L. K. Nash. It consists of three main parts: an analytical portion, a mercury vapour pump for transfer of the sample to the apparatus and a Topler pump for manipulation of the sample. In general, the method of analysis consists of measuring the volume of gas before and after treatment with various reagents and calculating the gaseous composition from the changes in volume.

The analytical portion is capable of determining small quantities of hydrogen, nitrogen, oxygen, carbon monoxide, carbon dioxide and methane. By means of the Topler pump, a sample can be circulated through reagent tubes containing magnesium perchlorate to remove water, ascarite to remove carbon dioxide and through an oxidising furnace for fractional combustion of carbon monoxide or hydrogen and methane. After each cycle of operations the pressure, volume and temperature of the gas in the burette is measured. The expected overall accuracy of analysis is ± 2%.

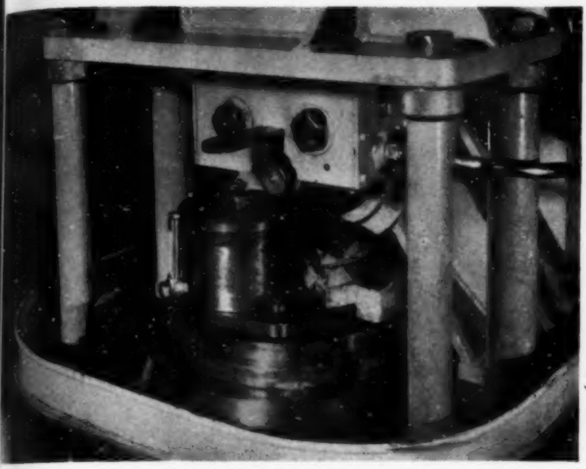
Turbine Blade Vibration

It is six years since the first impulse turbine designed at PAMETRADA went into service, and over 50 turbines of this type are now in successful operation. It is particularly gratifying to the designers that no case of blade vibration failure has been reported throughout this period, for the safeguarding of blades against vibration was a fundamental feature of this design. Nevertheless research continues on this subject, and, apart from straightforward fatigue testing of blades, other lines of attack are being used.

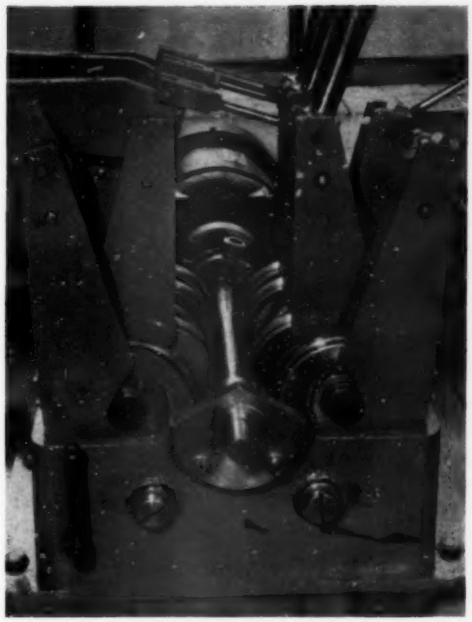
One investigation of interest is aimed at obtaining further data on the vibration of turbine blades excited by steam flow discontinuities. The turbine used for this investigation is ' inverted,' so that the nozzles rotate and



Scuffing of gear teeth.



Timken disc tester.



Niemann disc tester.

the blading is stationary. The developed power is absorbed and the speed controlled by a separately supplied brake turbine. The mode of vibration of the stationary blade pack can be observed stroboscopically and measured by magnetic pick-ups. The effect of excitation frequency, nozzle pitching, blade batching and nozzle grouping can be correlated. There is also an experimental compressor which is used for investigations of a variety of problems, including blade vibrations.

Gear Wear

PAMETRADA is studying the basic problems of gear tooth lubrication and materials, and the design of gear teeth. In addition, they are working on problems associated with marine gears, such as scuffing and pitting. Much of this work is done through the medium of small-scale disc tests, which simulate under continuous conditions the instaneous conditions between gear teeth. The next stage is to carry out trials of specially designed gears and of normal full-sized marine gears. This may be done incidentally during the course of machinery trials at sea, or the tests may be made on shore by using turbines to drive the gears and absorbing the power through a brake. A third alternative used at PAMETRADA is known as the power-circulator or back-to-back principle.

In back-to-back tests two similar gear boxes are arranged as a power circulation system, so that the driving turbine only has to overcome the frictional losses of the system. Whereas a 30,000 h.p. gear box,

Pitting of gear teeth.

tested by the more conventional method, would require to be driven by a 30,000 h.p. turbine, the use of a power circulation system makes it possible to test two 30,000 h.p. gear boxes up to full power, by using a turbine of about 1,500 h.p. The method depends on the introduction of equipment to provide the circulating torque in the system. PAMETRADA have developed a hydraulic torque loader by which the circulating torque can be applied, measured and changed during running.

It has been shown that the load-carrying capacity of gears can be increased very considerably by a small departure from true helical form. A tremendous improvement can also be gained by using hardened and ground gears, provided that the design of the gears and gear boxes is sufficiently stiff and that suitable gear-generating equipment for very hard materials is available.

For the microscopic examination of the pitting and scuffing on worn gear teeth, a method for making faithful replicas has been developed. It consists essentially of two processes: negative replicas of the surface are first cast in the field, using pre-fabricated ingots of purified sulphur and carbon black. Positive castings are then made from the negatives, using 'Alabastine.' Both replicas are of uniform colour so that variations in appearance are due to variations in surface texture only.

By viewing the replicas under a binocular microscope with very glancing illumination, it is possible to recognise differences in level, the surface details being enhanced by the throwing of shadows. The replicas can, alternatively be viewed through a metallurgical microscope, where photographs can be taken. Furthermore, it is possible to impress into the photographs, by a modification of Schmaltz's method, contour lines which allow the depth of scores to be evaluated.

The use of these methods has already led to the discovery that in certain hardened gear pairs material is excavated near the pitch line and re-deposited further away, independently of the direction of surface sliding

movements. This transference is apparently due to erosion, and the channels cut in some examples are about 0·0005 in. deep and of approximately rectangular section.

An alternative method of making negative replicas is to use a plastic compound 'Marco Resin.' This gives replicas particularly suited to the evaluation of the progress of pitting and the development of ridges in gears, but seems not to render microscopically fine detail as faithfully as the sulphur casts. On the other hand it appears superior for surface roughness measurements. Finally, a further possibility is to make transparent replicas in 'Perspex.' These allow of evaluating quantitatively the extent of pit areas.

In addition to gear and disc investigations, the mechanism of pitting is being studied by the micro-examination of sections cut from pitted teeth. Investigations along these lines has already led to a clearer understanding of the mechanism of pitting.

Miscellaneous Items

Gland Strip

Multi-strip glands are commonly used to form a seal between the rotor and casing of a turbine and small, clearances are necessary to minimise leakage. Any distortion of the casing or eccentricity of the shaft may result in rubbing contact between the rotor and the gland. A machine has been designed to obtain data on the behaviour of various materials and strip configurations when subjected to rubbing contact. Many cases of thermally bent rotors have occurred due to gland rubs. The machine has been inverted, so that the rotor is stationary and the gland housing rotates, to allow measurement of rotor temperature and expansion resulting from a controlled rubbing contact.

High Temperature Strain Gauges

Prefabricated strain gauges are required for fixing to unmodified machine parts which may approach a dull red heat, e.g., gas turbine blades. The method of manufacture employed by PAMETRADA comprises the stitching of thin wires to a heat-resisting carrier, the thin wires (0·001 in. dia.) then being welded to thicker ones with the aid of a microscope. The main problem is to find a cement which will withstand heat, thermal expansion, centrifugal stress and corrosive attack.

'Micropol' Electrolytic Polishing Machine

On sections too large to polish by conventional methods, this apparatus will produce a polished surface suitable for micro-examination. The polished area is about 1 mm. in diameter, and is free from the surface distortion that occurs with mechanical polishing.

Rolling Mill Contracts for South Wales

CONTRACTS worth £4 million have been secured by Davy and United Engineering Co., Ltd., Sheffield, for rolling mill equipment for installation in South Wales. They have been placed jointly by Richard Thomas and Baldwins, Ltd., and The Steel Company of Wales, Ltd., as the basis for a new large scale modernisation project for the Welsh sheet and tinplate industry.

The principal units to be built by Davy and United include a new 5-stand tandem cold strip mill and a 2-stand temper mill for the Ebbw Vale plant of Richard Thomas and Baldwins, Ltd. The new 5-stand mill will replace the existing 5-stand tamdem cold mill at Ebbw Vale, which was built before the 1939/45 war and is now considered obsolete. Large scale modifications to other mills and auxiliaries and the supply of much new ancilliary equipment will also be carried out, with the overall aim of increasing the Ebbw Vale plant capacity for cold rolled tinplate by some 2,000 to 2,500 tons per week.

Davy and United are also to build a further 5-stand tandem cold strip mill and two 2-stand temper mills for installation in a new tinplate works which the Steel Company of Wales are now establishing at Velindre, near Swansea. When completed, this plant will add another 9,000 tons per week of continuously produced tinplate to present South Wales capacity. A considerable amount of new hot and cold mill equipment will also be supplied to the Steel Company of Wales, Ltd., at Abbey Works. The completion of these contracts will mean that the total requirements of British produced tinplate —whether for home consumption or export—will be cold rolled by the most modern methods, with all the attendant advantages of improved quality and lower costs. The scheme now being implemented is in fact, the expression of the determination to maintain Britain in the forefront of world tinplate production.

Some twelve thousand tons of finished machinery will be supplied by Davy and United Engineering Company Ltd., against these contracts, in which the Company's two subsidiaries, Duncan Stewart & Co., Ltd., of Glasgow and Davy and United Roll Foundry, Ltd., of Middlesbrough, will also share. This total weight of machinery will include 32 roll housings which are single piece steel castings, each weighing at least one hundred tons.

The tinplate works of the Steel Company of Wales, Ltd., at Trostre, near Llanelly, which went into production last year was equipped with American built rolling mill and auxiliary machinery. This was due to the fact that when the Trostre scheme was in the planning stage some five or six years ago no British mill builder then possessed production resources on the requisite scale. The Velindre plant will be British built throughout, as will the new Ebbw Vale mills. The securing of these contracts for Britain comes as a direct result of the development of their works capacity which Davy and United have carried out in recent years. Their post-war expansion, carried out at a cost of £1½–£2 million, has now provided design and manufacturing capacity in this country which is easily capable of accepting orders of this magnitude, and of handling a number of such orders simultaneously without congestion. As a result, Britain's previous heavy dollar dependency for capital plant of this type has been effectively reduced. The bulk of these contracts now placed will be completed during 1955/6.

Change of Address

THE Manchester Office of the English Electric Co. Ltd., has been transferred to Croxley House, 14, Lloyd Street, Deansgate, Manchester, 2 (Telephone: DEAnsgate 7872/6).

The Corrosive Properties of Soluble Cutting Oils

Effect on Machine Tool Cast Irons

As a preliminary step to a study of the relative effects of selected soluble cutting oils on the efficiency of machining operations, PERA has investigated a number of properties of the oils in order to provide a reasonably accurate means of specification. In the course of this work the corrosive effect on cast irons used for machine tools was checked and this article is an account of the experiments carried out and the results obtained.

EXPERIENCE in industry and previous research investigations have shown that cutting fluids have an important influence on the efficiency of many machining operations. Nevertheless, very little reliable information is available to enable users of cutting fluids to select, with confidence, the most suitable cutting fluids for the machining operations with which they are concerned. Such information as is available is largely qualitative and subject in no small measure to the influence of personal opinions. There is undoubtedly a great need for quantitative data on the effects which cutting fluids have on tool life, permissible cutting speeds, surface finish obtained, etc. It is also necessary to have corresponding information regarding such phenomena as corrosion effects, fuming, physiological factors, etc., and as a first step towards providing this information, the Production Engineering Research Association of Great Britain (PERA) has undertaken a series of tests on a limited number of cutting fluids applied to a range of materials and machining operations.

Information on the properties of soluble cutting oils obtained in preliminary investigations, which has been available to PERA members for some time, has now been generally released. The results of an investigation into the corrosion of cast iron by a series of soluble cutting oils are presented in this article: other subjects investigated included lubrication properties; dispersion of oil particles; and wetting and spreading properties.

Corrosion of Machine Tools

The use of soluble oil emulsions on machine tools is always accompanied by a risk of damage to accurate machine tool surfaces, such as slides, through corrosion (see Fig. 1). The initial corrosion may not be serious in itself, but may give rise to serious pitting by causing metal particles to be trapped between mating surfaces. The effect is then cumulative and the accuracy of the machine tool may be seriously impaired. Another source of corrosion danger to machine tool parts such as spindles, gears, centres, etc., is the condensation of water evaporated from the soluble oil emulsion. This danger is inherent in all coolants using water, and only adequate cleaning and maintenance of the machine tool will afford protection against it. Yet another aspect of the corrosive action of a soluble oil concerns the workpiece. In cases where some time elapses between the machining of a component with the aid of a soluble oil emulsion, and a subsequent operation, it is often found that drops of the emulsion remaining on the workpiece cause staining. It has been found that as a rule cast iron is more susceptible to this form of attack, and that rough surfaces

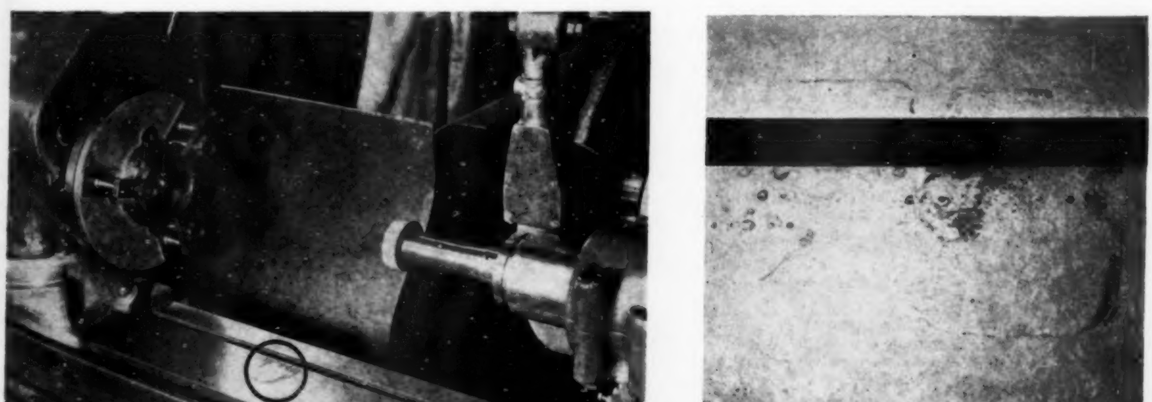


Fig. 1.—The corroded area faintly visible in the left-hand photograph is shown at approximately $\frac{2}{3}$ full size on the right.

Fig. 2.—Talysurf surface meter with test plate in position for measurement.

corrode more rapidly than highly-finished ones.[1] The object of the corrosion tests described below was not a fundamental study of the corrosion mechanism, but a practical determination of the extent of corrosion with a series of commercial soluble oils. The test method used was developed by Lloyd and Beeny,[2] who based their results on visual observation of the corroded areas. In the present investigation surface roughness measurement of these areas was carried out as an additional criterion.

As will be seen in the description of the method of corrosion testing, the plates were thoroughly cleaned and degreased prior to the test. This tended to remove the test from practical workshop conditions, since machine tool parts in a workshop would always have some grease or oil on them. Cleaning and degreasing were necessary for test purposes so that the plate surfaces were uniform at the start of each test. The absence of grease on the plate surfaces caused the corrosion marks to be much more severe than would be obtained on machine tool components under workshop conditions, but the considerable differences in the effect of the various emulsions permitted clear differentiation. This differentiation would also apply under workshop conditions, although the corrosion effect would be less severe.

Equipment

The cast iron plates used in the test were 4 in. square and their thicknesses were $\frac{1}{4}$ in., $\frac{7}{16}$ in. and $\frac{7}{8}$ in. for types (H), (S) and (C) respectively. The test surfaces were free from blow-holes or marks of any sort. The compositions of the irons set out in Table I, were similar to those used by three well-known machine tool makers for

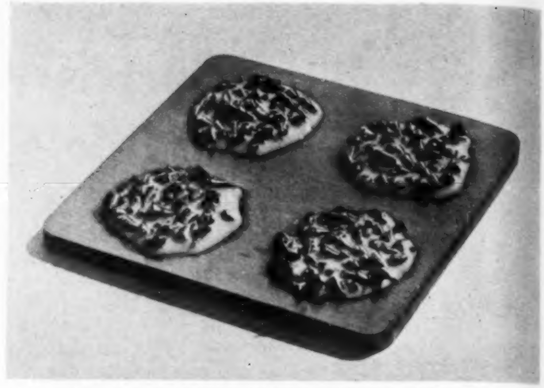


Fig. 3.—Test plate with drillings and emulsion.

machine bedways and slides. The steel chips were prepared by drilling steel of En8 specification with a $\frac{7}{16}$ in. drill. They were of fairly uniform length, the average being about $\frac{3}{8}$ in.; the drilling was done dry to avoid contamination and the chips were kept in a clean dry container.

The emulsions were mixed in measuring cylinders of 250 ml. capacity and applied to the plates by means of a graduated pipette. The majority of the tests were carried out with emulsions prepared with town mains water having a total hardness of 23·0 parts per 100,000 (temporary hardness 13·0 parts per 100,000; permanent hardness 10·0 parts per 100,000).

For the period of the test, the plates were kept in a test chamber approximately 3 cu. ft. capacity of wooden construction and fitted with rubber draught excluders and having three narrow shelves. A minimum-maximum type thermometer and an open dish containing saturated sodium bisulphate solution were placed at the bottom of the cabinet, the latter providing uniform relative humidity of approximately 52% at the test temperatures.

The surface roughness of the corroded areas was measured on the "Talysurf" surface meter. Both the average meter and recording meter were used. Fig. 2 shows the "Talysurf" with test plate in position for measurement.

Method

Eleven soluble oils, producing both milky and clear emulsions, were used in this investigation; the particulars are listed in Table II, from which it will be seen that the oils have been specified by their chemical analysis.

The complete analysis of soluble cutting oils, however, is a difficult process and the most careful treatment may not reveal the minute quantities of certain additives. In the course of the present investigations, therefore, tests were conducted to compare certain of the commercial oils with synthesised oils experimentally

TABLE I.—CHEMICAL ANALYSIS OF CAST IRONS USED FOR TEST PLATES

Element	H-plates	S-plates	C-plates
Total Carbon %	3·31	3·12	3·23
Graphite %	2·25	2·10	2·29
Combined Carbon %	1·06	1·02	0·94
Silicon %	1·87	1·85	2·59
Manganese %	0·64	0·38	0·53
Sulphur %	0·108	0·128	0·035
Phosphorus %	0·43	0·83	0·30
Nickel %	0·10	0·08	0·08
Chromium %	0·20	0·13	0·18
Molybdenum %	Nil	Nil	Nil

1 Stäger & Künzler. "Emulsionen für die Metallbearbeitlng," *Schweizer Archiv für Angewandte Wissenschaft und Technik*, 1943, **9**, (3 and 4).

2 Lloyd & Beeny. "Cutting Fluids and the Machine Tool," published by Alfred Herbert, Ltd., Coventry.

TABLE IIA.—ANALYSIS OF SOLUBLE CUTTING OILS USED FOR TESTS.

	Oil No. 1	Oil No. 2	Oil No. 3	Oil No. 4	Oil No. 5	Oil No. 6	Oil No. 7	Oil No. 8	Oil No. 9	Oil No. 10	Oil No. 11
Mineral Oil (non-volatile in steam) %*	64·4	81·3	41·4	52·8	69·4	37·2	62·6	80·9	27·4	39·7	91·6
Mineral Oil (volatile in steam) % ..	2·8	negligible	negligible	negligible	negligible	negligible	negligible	negligible	24·9	negligible	negligible
Water %	9·2	3·2	20·3	13·8	8·6	4·8	28·0	4·2	6·9	28·7	1·4
Petroleum Sulphonates % (M.W. = 420 assumed) %	7·4	12·6	5·6	2·9	3·2	—	—	—	—	—	—
Petroleum Sulphonates %	—	—	—	—	—	18·8	—	2·5	1·8	9·5	1·8
Phenols %	—	—	—	—	—	—	—	—	—	—	—
Phenols (assumed cresylic acid) % ..	3·7	—	—	—	0·5	—	—	—	—	—	—
Cresylic Acid %	—	—	9·8	5·0	—	5·4	—	0·5	3·8	2·2	—
Rosin Soaps %	11·8	—	—	—	—	22·2	—	11·2	30·9	20·0	—
Carboxylic Soaps (M.W. = 300 assumed) %	—	2·4	—	—	—	—	—	—	—	—	—
Naphthenic Soaps %	—	—	22·8	25·2	—	—	9·4	—	—	—	5·4
Naphthenic Soaps (principally sodium soaps, confirmed by spectrograph)%	—	—	—	—	19·8	—	—	—	—	—	—
Fatty Oil %	—	—	—	—	—	11·8	—	—	—	—	—
Unaccounted for %	—	—	—	—	—	—	—	—	4·3	—	—
Acid Value of Carboxylic Acid Fraction	174	—	170	161	189	138	166	130	160	145	178
Molecular Weight of Carboxylic Acid Fraction (determined)	—	—	330	348	297	—	—	—	—	—	—
Molecular Weight of Carboxylic Acid Fraction (calculated)	322	—	—	—	—	405	337	431	351	386	315

* % indicates per cent. weight/weight.

prepared to the same analysis. The machining test results with these oils showed correlation varying from 100% to approximately 85%, all the experimental oils being in the same statistical performance group as their commercial counterparts. The dispersion of the experimental emulsions was very similar to the dispersion of the commercial emulsions, and corrosion test results, with one exception, also correlated satisfactorily. The exceptional case involved a commercial soluble oil believed to contain a corrosion inhibitor not identified in the analysis. In general, therefore, it appears that analysis of soluble oils is possible and that the details of the manufacturing process do not unduly affect the performance of the soluble oil emulsion. However, before the effect of particular constituents is fully known further fundamental research on this subject is required. The present tests are essentially practical tests for the benefit of makers and users of soluble oils and cannot take the place of a fundamental investigation into the effect of varying quantities of single constituents of soluble oils on the physical properties and performance during cutting.

Tests were carried out on three types of cast iron plate, each soluble oil being diluted to form three emulsions of varying strengths. The dilution ratios were 1 : 10, 1 : 15 and 1 : 25, corresponding to dilutions used for general machining purposes. An analysis of the results of these tests was intended to reveal the extent of corrosion in general and the influence of emulsion type and dilution, and plate material. The additional tests in which distilled water was used were carried out to assess the influence of water hardness and purity on the extent of corrosion.

The cast iron plates were ground to ensure a level surface and a preliminary finish was obtained with emery cloth No. 0. They were then cleaned and degreased successively with benzine and acetone and finally finished with emery cloth No. 0. This second finishing operation was performed by rubbing the cast iron plates on emery cloth placed on a glass plate. Emery particles and metallic dust were then removed by wiping the plate with clean cotton wool.

Steel chippings weighing approximately 2g. were then placed on the plate in four piles, one in each quarter of the plate surface. They were then spread out so as to cover an area approximately 1·3 sq.in. To avoid contamination, clean glass rods were used for arranging

TABLE IIB.—NOTES ON SOLUBLE CUTTING OILS USED FOR TESTS.

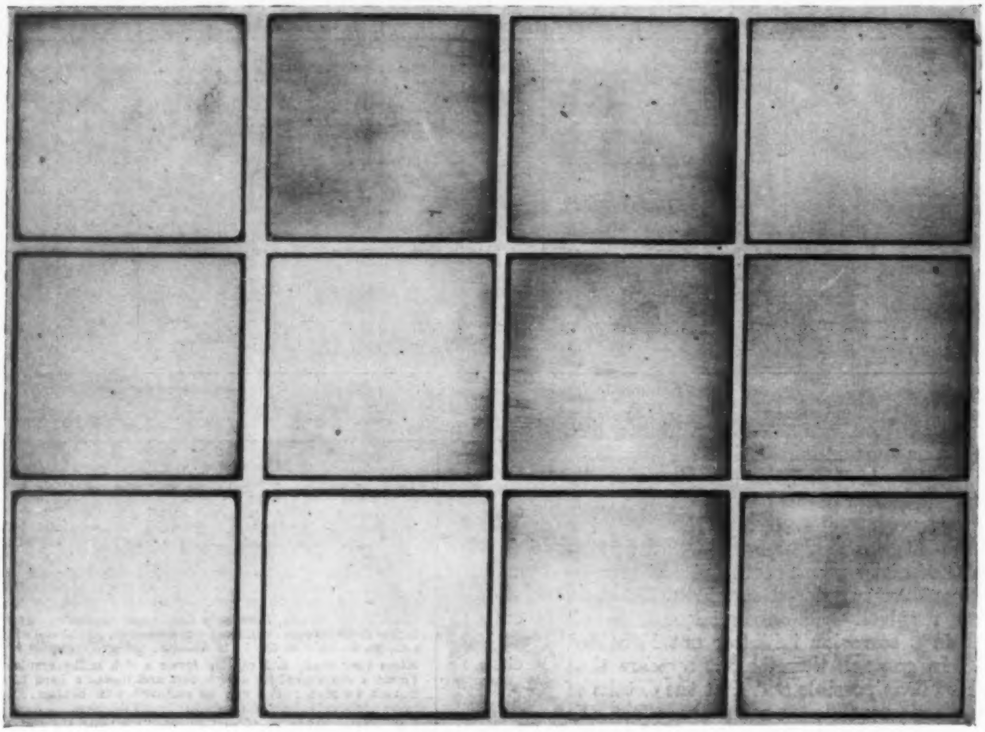
Oil No. 1	Mixes easily, rapidly forming a whitish, semi-transparent emulsion. There was no separation during the test and no deposit was left on the plate.
Oil No. 2	Mixes easily, forming a rich, white emulsion. Some separation took place during the test, with consequent rusting on the periphery of the corroded areas. Some deep green deposition plates.
Oil No. 3	Fairly rapid mixing, resulting in a clear light straw-coloured emulsion. Some separation, causing rusty deposit, particularly at higher dilution. Thick green deposit left on plate after test.
Oil No. 4	Mixes fairly rapidly, forming a dark clear emulsion. At the higher dilutions some milkiness was noticeable at the end of the test, particularly at the 1 : 25 dilution.
Oil No. 5	Mixes very easily and rapidly forms a rich milky emulsion. Forms a rusty product during test and leaves a hard black deposit on plate; this can be removed with benzine. The rusty product is more noticeable at higher dilution.
Oil No. 6	Does not emulsify easily and has to be stirred considerably before forming a clear dark emulsion. There was some separation during the test, producing slight rusty and green deposit.
Oil No. 7	Mixes rapidly, forming a milky emulsion. Considerable separation took place during test, with water collecting around the periphery. This was particularly pronounced at high dilution and with mains water. Rusting and deposit formation were considerable at periphery and slighter in centre of area.
Oil No. 8	Mixes rapidly, forming a milky emulsion. Almost no separation during test period and very little deposit.
Oil No. 9	Forms a clear dark emulsion, mixing fairly slowly. Separates only very slightly and only at higher dilutions. At the higher dilutions there is also some slight deposit.
Oil No. 10	Mixes rapidly, forming a clear, light straw-coloured emulsion. At the two higher dilutions some milkiness and a little deposit were noticeable; very erratic results were repeatedly obtained with this oil.
Oil No. 11	Mixes readily and forms a rich white emulsion. There was no separation or deposit during the tests with the exception of one, at 1 : 25, where slight separation took place.

the chips. The emulsion was then applied to the four areas from a 5 ml. pipette, 3 ml. of fluid being placed on each area so as to cover all the chips, as shown in Fig. 3. The plates were transferred to the cabinet and placed on glass strips resting on shelves. The temperature and humidity of the cabinet were controlled and the maximum and minimum temperatures during the test period were recorded. These ranged from 54° F. to 62° F. After 24 hours the plates were removed, notes made of any noticeable separation, and the drillings and emulsion removed from the plates. These were then cleaned and degreased. The corrosion was then assessed visually as follows :—

Grade	0	1	2	3
Area	None attacked	1/3 attacked	2/3 attacked	Whole area attacked
Intensity ..	None	Slight	Medium	Heavy

DISTILLED WATER — TOWN MAINS WATER

DISTILLED WATER	TOWN MAINS WATER		
H Plates	C Plates	S Plates	H Plates

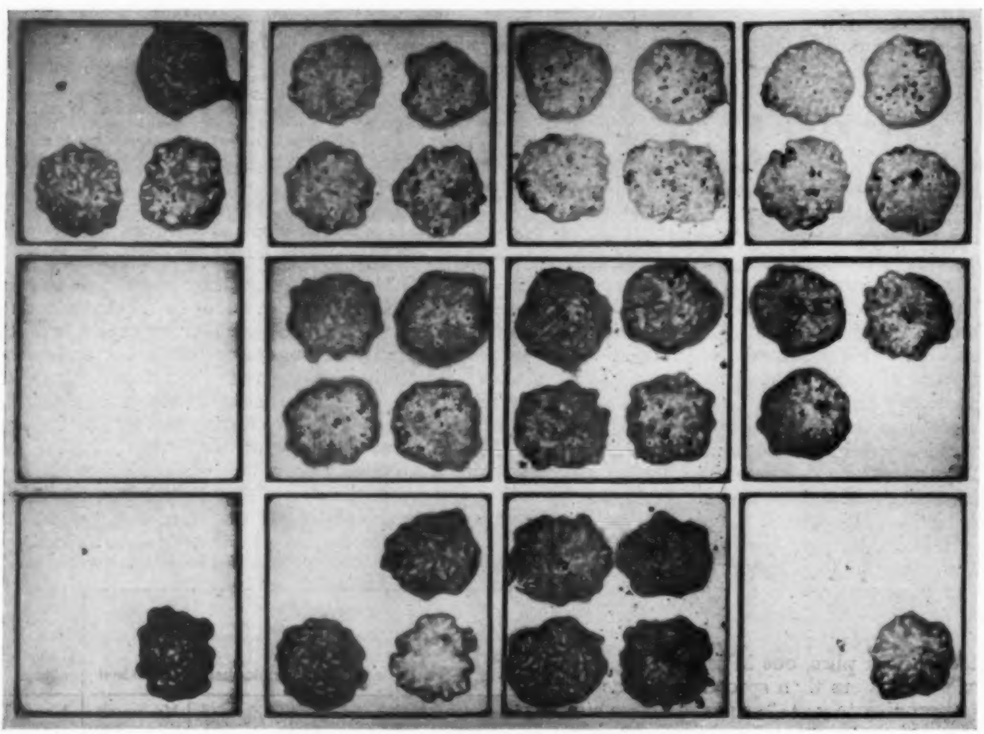


1: 25

1: 15

1: 10

Fig. 4.—Corrosion test plates—Oil No. 1.



1: 25

1: 15

1: 10

Fig. 5.—Corrosion test plates—Oil No. 3.

DISTILLED WATER | TOWN MAINS WATER
H Plates | C Plates | S Plates | H Plates

1: 25

1: 15

1: 10

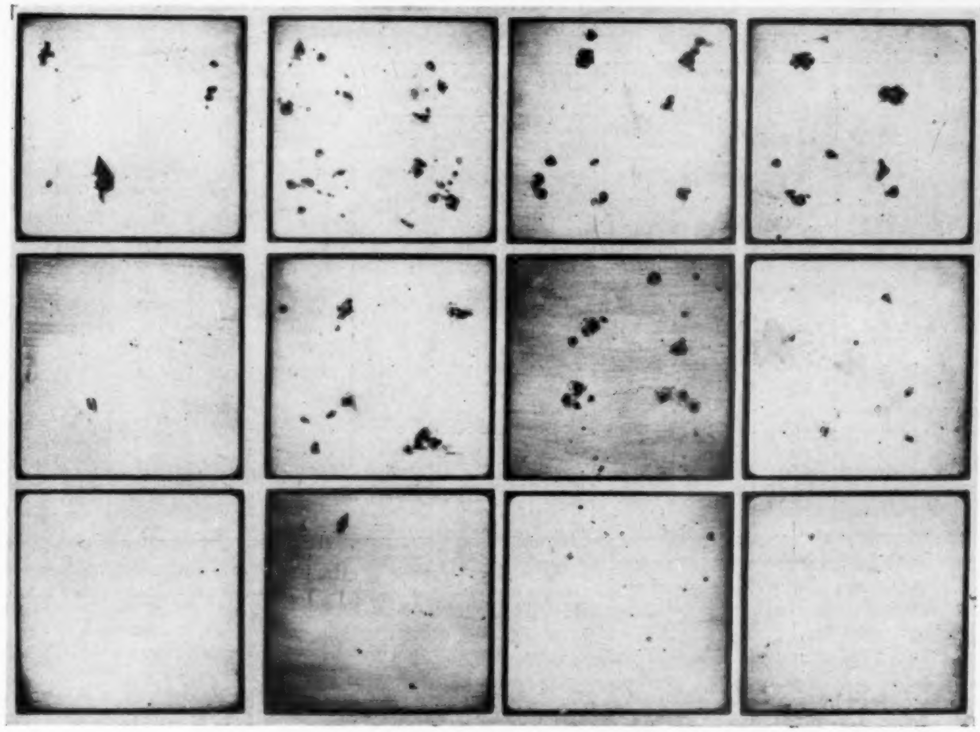


Fig. 6.—Corrosion test plates—Oil No. 4.

1: 25

1: 15

1: 10

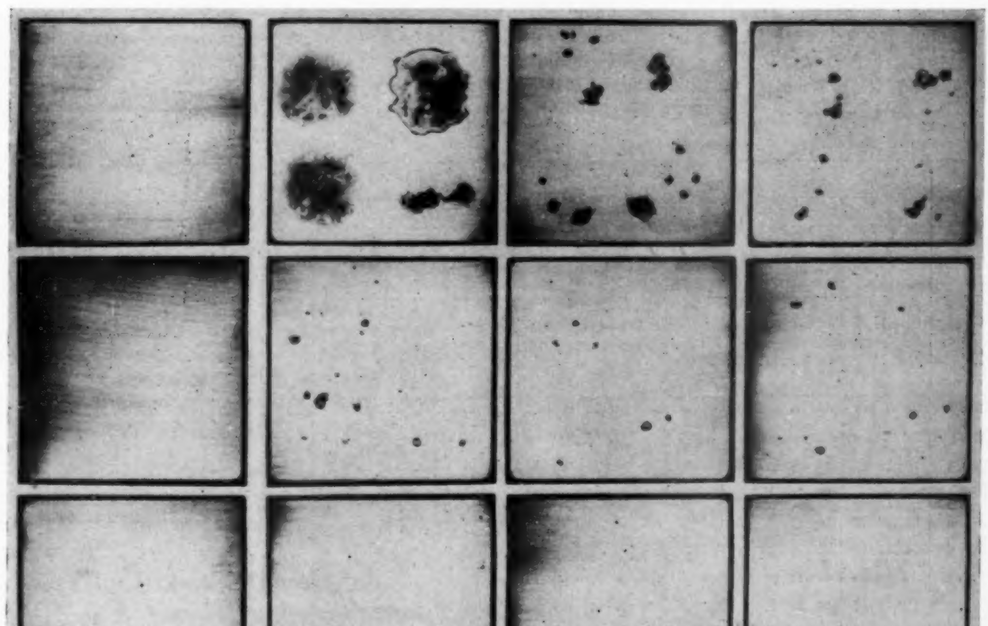


Fig. 7.—Corrosion test plates—Oil No. 9.

TABLE III.—VISUAL AREA AND INTENSITY GRADING

		Town Mains Water									Distilled Water		
		H-plates			S-plates			C-plates			H-plates		
		1 : 10	1 : 15	1 : 25	1 : 10	1 : 15	1 : 25	1 : 10	1 : 15	1 : 25	1 : 10	1 : 15	1 : 25
Oil No. 1	Area	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
	Intensity	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
Oil No. 2	Area	2222	2222	1000	2222	2222	1100	2222	3222	3333	3333	3333	3333
	Intensity	2222	2222	1000	2222	1111	1100	2222	1111	1111	3333	3333	3333
Oil No. 3	Area	3000	3330	3333	3333	3333	3333	3330	3333	3333	3000	0000	3330
	Intensity	1000	2220	2222	1111	2222	2222	1110	1222	2222	2000	0000	2220
Oil No. 4	Area	0000	1111	1111	0000	1111	1111	0000	1111	1111	0000	1000	1110
	Intensity	0000	1111	1111	0000	1111	1111	0000	2222	2222	0000	1000	2110
Oil No. 5	Area	2222	2222	2222	2222	2222	2222	2222	2222	3333	2222	2222	3322
	Intensity	3333	3333	3322	3333	2222	2222	3333	2222	1111	3333	3333	3333
Oil No. 6	Area	3333	3333	3333	3333	3333	3333	3333	3333	3333	2222	3333	3333
	Intensity	1111	1222	1222	2222	2222	2222	2222	2222	2222	2222	2222	2222
Oil No. 7	Area	3333	3333	3333	3333	3333	3333	3333	3333	3333	3220	3222	3333
	Intensity	2222	2222	2222	2222	2222	2222	2222	2222	2222	1220	2211	2221
Oil No. 8	Area	1111	1111	1111	1111	1111	1111	1111	1111	1111	2100	1100	1111
	Intensity	2222	2222	2222	2222	2222	2222	2222	2222	2222	1200	2200	1111
Oil No. 9	Area	0000	1111	1111	0000	1110	1111	0000	1110	3222	0000	0000	0000
	Intensity	0000	2222	2222	0000	2220	2222	0000	2210	2222	0000	0000	0000
Oil No. 10	Area	0000	2200	2220	0000	2200	2220	0000	2200	3330	0000	0000	0000
	Intensity	0000	2200	2220	0000	2200	2220	0000	2200	2220	0000	0000	0000
Oil No. 11	Area	1111	1111	1111	1110	1111	1111	1111	1111	2211	1000	1000	1111
	Intensity	2222	2222	2222	2220	2222	2222	2222	2222	2222	2000	2000	2222

The visual grading frequently presented considerable difficulties because the wide range of each grade enabled widely varying areas to be similarly graded. Further, the various emulsions produced different types of corrosion marks, which made intensity grading difficult.

After visual grading the plates were photographed and the surface roughness measurement was carried out. The plates were placed on the Talysurf table and average readings were taken on the corroded areas as well as on those not covered by the emulsion. These readings were recorded on a tracing of the plate and surface records of areas most affected were then taken, the magnification used varying according to the degree of pitting. The plate surfaces were covered with a special protective oil so that no further corrosion could take place whenever

TABLE V.—INCIDENCE OF PITTING.

Oil No. 1	No pitting.
Oil No. 2	No definite signs of pitting.
Oil No. 3	Severe pitting was present in many of the corroded areas.
Oil No. 4	No pitting.
Oil No. 5	Despite the bad appearance of the corroded areas there was an absence of pitting.
Oil No. 6	Surface records showed no definite pitting.
Oil No. 7	Pitting was confined to the periphery, where it occurred fairly frequently.
Oil No. 8	Pitting was, on the whole, rare, but was fairly deep where it did appear.
Oil No. 9	Pitting was very rare and relatively small where it did appear.
Oil No. 10	There was no pitting which could definitely be ascribed to corrosion.
Oil No. 11	No definite evidence of pitting.

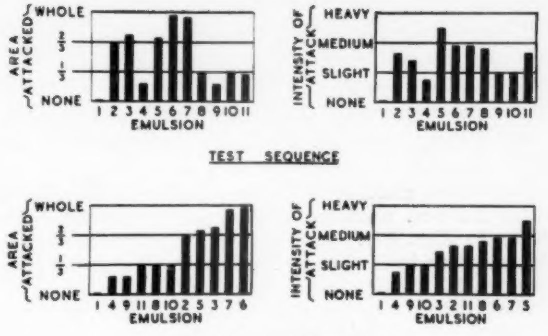
TABLE IV.—SUMMARY OF SURFACE ROUGHNESS READINGS

	Town Mains Water																	
	H-plates									S-plates								
	1 : 10			1 : 15			1 : 25			1 : 10			1 : 15			1 : 25		
	h (average) (mu. in.)			h (average) (mu. in.)			h (average) (mu. in.)			h (average) (mu. in.)			h (average) (mu. in.)			h (average) (mu. in.)		
	Corroded Areas	Plates	Difference	Corroded Areas	Plates	Difference	Corroded Areas	Plates	Difference	Corroded Areas	Plates	Difference	Corroded Areas	Plates	Difference	Corroded Areas	Plates	Difference
Oil No. 1*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oil No. 2	22	16	6	24	20	4	—	—	—	26	15	9	20	15	5	—	—	—
Oil No. 3	15	12	3	45	20	25	50	18	32	40	18	22	40	16	24	60	14	46
Oil No. 4	—	—	—	22	13	9	20	14	6	13	14	−1	16	14	2	11	10	1
Oil No. 5	25	10	15	20	12	8	22	11	11	22	10	12	20	10	10	15	12	3
Oil No. 6	14	15	−1	20	15	5	14	14	0	14	15	−1	16	14	2	12	10	2
Oil No. 7	25	12	13	40	13	27	40	16	24	35	15	20	30	15	15	30	15	15
Oil No. 8	15	14	1	35	14	21	15	15	0	35	12	23	12	12	0	15	13	2
Oil No. 9	—	—	—	—	—	—	20	12	8	—	—	—	14	15	−1	20	13	7
Oil No. 10	—	—	—	14	14	0	14	16	−2	—	—	—	12	12	0	20	16	4
Oil No. 11	25	18	7	22	14	8	28	20	8	22	17	5	24	22	2	20	10	10

	Town Mains Water									Distilled Water								
	C-plates									H-plates								
	1 : 10			1 : 15			1 : 25			1 : 10			1 : 15			1 : 25		
	h (average) (mu. in.)			h (average) (mu. in.)			h (average) (mu. in.)			h (average) (mu. in.)			h (average) (mu. in.)			h (average) (mu. in.)		
	Corroded Areas	Plates	Difference	Corroded Areas	Plates	Difference	Corroded Areas	Plates	Difference	Corroded Areas	Plates	Difference	Corroded Areas	Plates	Difference	Corroded Areas	Plates	Difference
Oil No. 1*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oil No. 2	22	16	6	20	12	8	25	20	5	18	18	0	22	15	7	20	16	4
Oil No. 3	18	18	0	28	16	12	55	14	31	15	15	0	—	—	—	24	14	10
Oil No. 4	—	—	—	28	11	17	20	15	5	—	—	—	35	18	17	12	12	0
Oil No. 5	26	12	14	28	14	14	20	14	6	24	15	9	28	15	13	20	15	5
Oil No. 6	8	9	−1	7	7	0	6	6	0	24	20	4	18	13	5	20	16	4
Oil No. 7	35	20	15	35	12	23	35	12	23	20	14	6	20	15	5	20	16	4
Oil No. 8	35	11	24	14	10	4	20	8	12	22	16	6	30	16	14	18	18	0
Oil No. 9	—	—	—	12	14	−2	30	12	18	—	—	—	—	—	—	—	—	—
Oil No. 10	—	—	—	30	20	10	16	18	−2	—	—	—	—	—	—	—	—	—
Oil No. 11	30	15	15	26	15	11	28	22	6	—	—	—	—	—	—	20	12	8

* No measurements were made, as there were no corrosion marks.

Fig. 8.—Chart comparing corrosive action produced by soluble oil emulsions, based on averages of all tests.



an interval occurred between visual grading, photographing and surface measurement.

It will be noted from the description of the method used in the corrosion tests that great importance was attached to the consistency of test plate preparation and test conditions in general. The influence of slight variations in these conditions on the corrosive action could have been considerable, particularly in cases where risk of corrosion is low. A short series of tests was therefore conducted, varying the method of plate preparation and temperature and humidity conditions during the test period to correspond to a range of conditions which may be met if the test is to be carried out in factories.

In the first set of these tests, plates were prepared in three different ways :—

(1) Plate finished with emery cloth No. 0, degreased with benzene and acetone and finally finished with emery cloth No. 0.

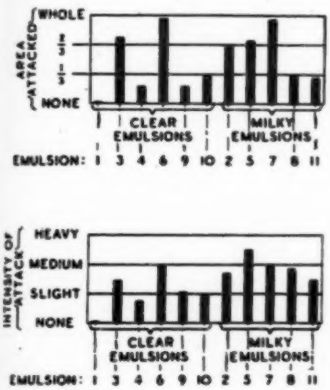


Fig. 9

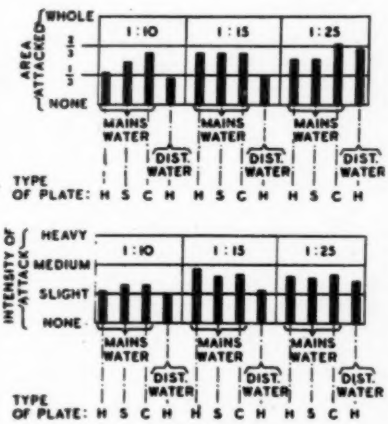


Fig. 10

Fig. 9.—Chart comparing corrosive action produced by clear and milky soluble oil emulsions, based on visual gradings of all tests.

Fig. 10.—Chart comparing corrosive action produced by soluble oil emulsions at three different dilutions, based on visual gradings of all tests.

(2) Plate finished with emery cloth No. 0 and not degreased.

(3) Plate finished with emery cloth No. 0 and a thin film of machine oil spread on the plate surface.

The results showed that there was little difference in area and intensity of corrosion between the plates prepared by methods (1) and (2). The plates prepared by method (3) were also corroded, but the intensity and area were one grade lower than the other plates. The total area covered by corrosion marks was about the same as on the other plates, but within this area there were spots free from corrosion.

In the second set of tests, the plates were prepared by the standard method, but for the 24-hour test period they were placed in positions with different temperature and humidity. These were :—

(1) Test cabinet, with temperature approximately 55° F. and humidity controlled by the inclusion in the cabinet of an open dish containing a saturated sodium bisulphate solution.

(2) Shelf directly above a heating radiator, with temperature of approximately 65° F. and relatively dry atmosphere.

(3) Out of doors, with temperature varying from 40°—50° F. and a damp atmosphere.

Under these three conditions the differences in area and intensity of corrosion were not more than one grade between any two test areas.

The results of these two sets of tests indicate that, under the particular test conditions used, the influence of variations in plate preparation and temperature and humidity during the test was small. In order to obtain comparative results, however, it is recommended that test conditions, even though they may differ slightly from those fully described in this report, should be strictly controlled.

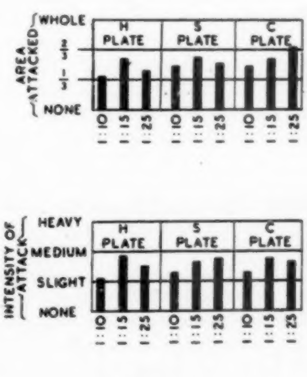


Fig. 11

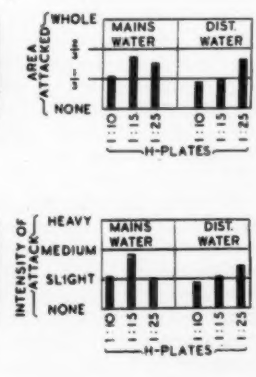


Fig. 12

Fig. 11.—Chart comparing corrosive action produced by soluble oil emulsions on three types of cast iron, based on visual gradings of all tests.

Fig. 12.—Chart comparing corrosive action produced by soluble oil emulsions prepared with mains water and distilled water, based on visual gradings of all tests conducted on one type of cast iron.

Results

There were three criteria for assessing the corrosion marks on the plates :—

(1) Visual grading.

(2) Average surface roughness of corroded areas.

(3) Pitting of corroded areas as revealed by surface records.

The visual grading results are shown collectively in Table III and photographs of typical test plates are shown in Figs. 4–7. Surface roughness readings of the plates before test, of corroded areas, and the difference between the two values are summarised in Table IV, whilst Table V refers to the incidence of pitting. Fig. 8 compares the corrosion caused by the various emulsions and is based on the results of all the tests, whilst Figs. 9–12 show the extent to which dilution, plate type, and water quality affect the area and intensity of corrosion.

Conclusions

(1) Considerable differences in corrosive action were found with various soluble oils, suggesting that careful selection is warranted to avoid deterioration of machine tool parts.

(2) In general, clear soluble oils showed less corrosive effect than milky soluble oils. There were, however, notable exceptions.

(3) The use of distilled water for preparing the emulsion, in place of town mains water, appeared to give a slight but inconsistent decrease of corrosion.

(4) In general, the 1 : 10 dilutions of soluble oil caused less corrosion than the 1 : 15 and 1 : 25 dilutions. There was no marked difference between the two higher dilutions.

(5) By comparative tests with three types of cast iron, as used by various machine tool makers, it was established that no one cast iron of those tested was more liable to corrosion than another.

Recommendations

The considerable differences in corrosive effect which were found with the various soluble oils justify careful selection, and a simple test, such as used in this investigation, should be applied to all incoming soluble oil supplies.

To obtain a stable, yet economical emulsion, the makers' recommendations should be followed when mixing. The method of mixing as well as the dilution ratio are of importance. There is no standard method of mixing for all soluble cutting oils, and, therefore, makers' instructions are the safest guide.

The corrosive activity depends largely on the combined action of metal chips and the emulsion. A stable emulsion alone causes little or no corrosion on the cast iron surface. Careful removal of chips from the important machine tool surfaces after use or before an idle period should prevent serious corrosion.

A grease film over the surface prevents or delays corrosion and at no time should vulnerable machine tool parts be without such a protective film.

New Hammer Forge at Steel, Peech & Tozer

OPERATIONS have recently commenced at the new hammer forge, which Steel, Peech & Tozer have built at their Ickles works. This forge is designed to give increased production and to apply the latest techniques to the manufacture of railway axles. The new building consists of two bays, one 320 ft. long by 70 ft. wide and the other 240 ft. long by 55 ft. wide. Each bay is served by a 5-ton E.O.T. crane, fitted with a magnetic attachment. The principal items of equipment are a continuous gas-fired furnace, a 7-ton steam-operated hammer, an electrically operated mechanical manipulator, a second furnace and oil tank for heat treatment purposes, a straightener and cold sawing equipment. A 5-ton hammer and two batch-type furnaces are also included for general forging purposes. The lay-out of the equipment has been designed on continuous flow principles and permits an output exceeding one hundred axles per shift to be achieved.

The axle blooms are transported in wagons from the Templeborough Mills, and are unloaded and stacked by an overhead crane. Each bloom is charged as required into the continuous heating furnace, through which it is pushed, being gradually heated to a temperature of 1,250° C.

On reaching the end of the furnace, it is pushed out down a gravity roller rack to the manipulator. The manipulator grips the bloom by means of specially designed tongs, and while forging is taking place rotates the bloom, on which a constant stream of water is played from a series of jets. This ensures the removal of scale and gives a clean forged surface. Heat-resisting safety glass protects the operator from flying scale and direct heat. When one end of the bloom has been forged, the manipulator places it on a turntable where it is rotated through 180°. The manipulator then grips it by the forged end and returns it to the hammer.

On completion of forging, the axle is placed on a tilting gantry and raised to the height of the heat treatment furnace hearth. It rolls through this furnace by gravity, and is heated to a temperature of approximately 850° C. On emerging from the furnace, it rolls on to a cradle above an oil-bath. If it is to be oil-quenched, the cradle is submerged for a pre-determined time ; when the cradle is raised a special ejecting mechanism comes into action and the axle rolls off on to the adjacent turn-table. If the axle is to be normalised instead of oil-quenched, it rolls straight over the oil-tank to a turn-table. After being rotated through 90°, the axle moves along to the cooling racks, from which it passes to the straightener, where any eccentricity is corrected. After straightening, the ends are cold sawn and the axle is then despatched either by road to Messrs. Owen & Dyson for machining, or by rail if it is to be supplied to the customer in the as-forged condition.

Birmingham Productivity Association

THE first trade body to affiliate to the newly formed Birmingham Productivity Association is the Cold Rolled Brass and Copper Association. The trade association, at a members' meeting, accepted a recommendation for affiliation put forward by its own recently appointed Productivity Committee, which is examining ways and means of reducing costs by improving efficiency in the industry.

Metal Casting Methods

VIII—Gating and Feeding Practice

By J. B. McIntyre, M.Sc., A.I.M.
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Continuing this series of articles on metal casting methods, the author deals mainly with the gating and feeding of sand castings, and with the use of chills and deuseners. He concludes with a brief reference to jobbing and mechanised moulding.

MUCH of the skill required for the successful production of sand castings lies in the techniques used to avoid mould erosion, and to compensate for the liquid shrinkage occurring as the casting cools to the solidus temperature. The decrease in volume which occurs is dependent upon the composition of the alloy, and the amount of superheat present: values have been established, for many pure metals and alloys, from which the shrinkage may be calculated for a given casting temperature. Solidification is somewhat complicated in shaped castings which have been cast in metal moulds, but sand castings freeze in an even more complicated manner, owing to the comparatively low thermal conductivity of the moulding material. The varied section thicknesses result in uneven solidification rates, and internal cores increase the difficulty. The primary function of a mould is to receive the molten alloy and then to dissipate its heat content. Heat transfer proceeds mainly in two ways: a limited chilling effect is exerted by the mould material immediately after pouring, and then heat transfer is mainly due to conduction through the mould walls. Many workers have carried out experiments designed to assess the solidification rate in various castings.

Runners and Risers

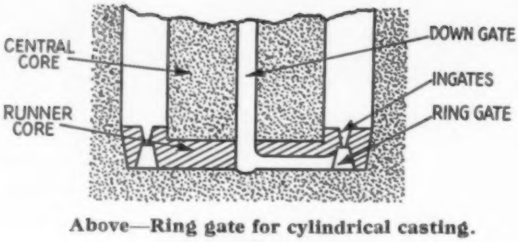
The mould filling operation is very important, and incorrect technique can nullify all previous work on the mould. The metal pouring technique should serve a threefold purpose: the mould cavity should be completely filled; the mould material should not be attacked; and appropriate thermal gradients should be established in the casting. Since shaped castings are usually required without extensive machining, the additional metal supply provided to combat the ill-effects of shrinkage should be placed so that it can be readily removed when solidification is completed. The method used to introduce liquid metal into the mould cavity is generally referred to as "the running system," while the reservoirs of liquid metal used for feeding purposes are known as "risers." When certain castings are made in alloys of low shrinkage capacity, the running and riser systems may be combined. Many workers have attempted to develop running systems capable of application to any shaped casting. Such methods have not been widely used, nor are they always effective in practice. Castings of simple design may be readily produced by standard running methods, but the majority of shaped castings are not simple. Variations in specific heat, mould filling capacity, and casting temperature, will introduce so many variables that any mathematical treatment of the problem cannot be precise. Stack moulding methods, and casting techniques involving the use of bottom pouring ladles, render any theoretical approach extremely difficult. The non-ferrous casting field is particularly complicated, as many of the alloys in common use are readily oxidised or chilled. Superheating may not always be possible, since gas solubility effects may be increased, and it is known that an undesirably large grain size can result if high casting temperatures are used for tin bronze castings. This is also the case in most other alloys of foundry importance. Grey cast iron and certain magnesium alloys may be improved, to some extent, by superheating.

The principles involved in the production of shaped castings are very similar to those observed in steel ingot production. Scores of running methods find general application, and at least one complete textbook dealing with this subject has been published. Most of the running techniques which are now established in foundry practice have been developed empirically, and much controversy has arisen over the efficiency of each method. Running systems which are technically efficient are relatively common, yet many of these can be regarded as uneconomic. Continental running techniques are admirable in many respects, yet often tend to be complicated. Simplicity in running and feeding methods is always desirable, since moulding, cleaning and fettling operations are thereby facilitated.

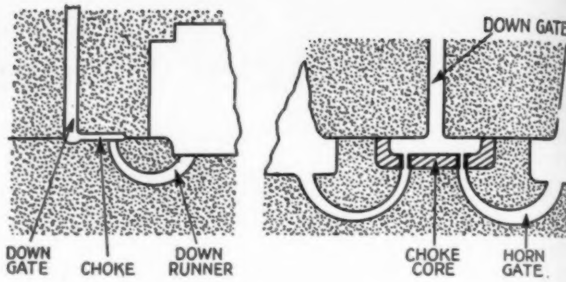
Metal Yield

The weight of any finished casting when ready for delivery, and when still in the unmachined state, is appreciably less than that of the liquid alloy required to produce it. The ratio of these weights is called "the yield," and may be expressed as a percentage. Yields vary considerably according to casting design, alloy type, and the production method chosen. Alloy type exerts a profound influence in every case, and apparently dissimilar alloys may often be used for casting production provided that the metallurgical characteristics are similar. Large marine pump bodies, for example, are often produced in either grey cast iron or gunmetal, according to requirements; the same pattern equipment and running techniques are used in each case. Turbine runner castings are regularly produced in high chromium steel and also, to a lesser extent, in manganese bronze. Few foundries are equipped to process both alloy types, yet since dross formation and shrinkage capacity are similar in the two cases the production techniques adopted are also similar, though developed independently.

In all cases, the mould cavity should be filled so that gradual solidification in the desired direction is promoted.



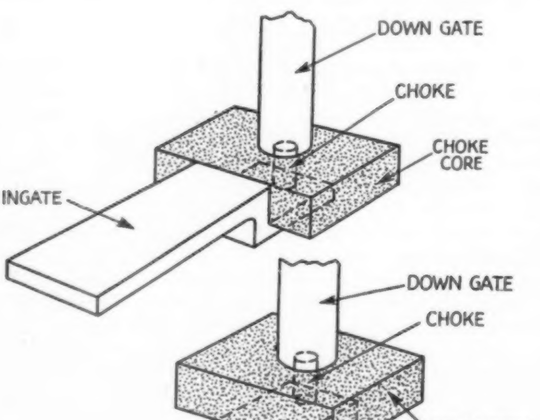
Above—Ring gate for cylindrical casting.
Right—Horn gates.



Theoretically, the ideal conditions are obtained if top pouring techniques are used, and a slow rate of pouring maintained. Bottom pouring methods should be avoided since the liquid alloy entering the mould cavity is gradually cooled as it traverses the internal surfaces of the mould. Simultaneously, the lower parts of the mould are preheated ; the undesirable thermal gradients established when bottom pouring methods are used prevent efficient feeding conditions, and secondary piping can thereby be facilitated. The horn gating methods illustrated are widely used in bottom pouring systems, in order to minimise turbulence. Horn gates cannot be cut conveniently by hand, and are usually incorporated in the pattern equipment. The Stone runner illustrated is technically superior, and is more easily moulded than any of the more usual horn gates. This method of gating can be applied to any alloy which is liable to dross formation.

Overcoming Bottom Pouring Effects

Many ingenious devices have been suggested to overcome the ill-effects of bottom pouring methods. The mould reversal techniques proposed by Batty are quite efficient in this respect, but are rather difficult to practise in ordinary foundry work. Partial reversal methods of the type illustrated are more popular. Step gating systems have been practised for very many years, but the valuable work carried out in the U.S.A. Naval Research Laboratory tends to show that such



Runner systems suitable for maganese bronze.

methods are not always effective. "Top filling" or "after pouring" of hot metal into risers is often used to secure favourable thermal conditions within the mould. Since the majority of castings have more than one riser, it is extremely difficult to avoid displacing comparatively cold metal from the mould cavity into the remaining risers while hot metal is being added. Genders and Bailey carried out a series of extremely interesting experiments over 20 years ago, in which two copper-base alloys of similar specific gravity and freezing point were cast consecutively into a deep metal ingot mould of small cross section. The materials concerned were 90-10 red brass, and 50-30-20 nickel silver, which is practically white in colour. The brass was poured first into the mould, and the nickel silver poured immediately afterwards. After solidification, the composite ingot was sectioned vertically and the red, yellow and white zones present indicated that considerable displacement of liquid occurred within the mould as pouring proceeded. A series of such experiments established that displacement was inevitable, but was dependent to some extent upon the pouring method used. Single stream top pouring methods caused more displacement than similar methods of the multi-hole tundish type. Bottom pouring was less objectionable, but some displacement still occurred.

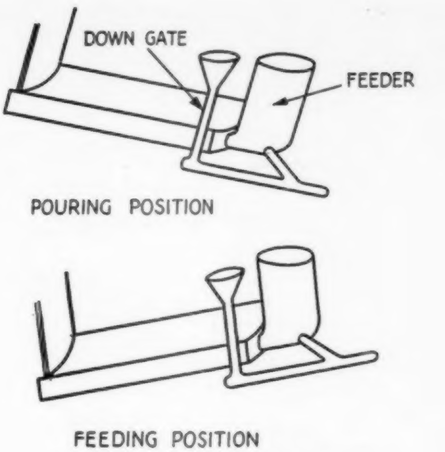
It is obvious that similar effects must be obtained in the majority of sand moulds which are of relatively intricate internal shape. The writer investigated the cause of dross inclusions in small aluminium bronze marine propellers, and established that this defect was due to "top filling" after bottom pouring. This technique is not recommended, therefore, when clean sound castings are to be made from alloys liable to dross formation. There is no doubt that alloys containing aluminium and chromium are more liable to suffer from oxide inclusions than are the remaining common alloys of foundry interest. Joint running methods are widely used for such materials, since the drag half of each mould is virtually top poured, while the cope is bottom poured. In this way turbulence is reduced, and the effects of adverse thermal gradients are minimised. Similarly, the number of ingates used in any mould should be restricted in order to reduce fettling costs, yet it is advisable to use the maximum number if good heat distribution and rapid mould filling are to be attained. Compromise is the keynote of foundry practice.

Feeding Methods

The choice of feeding method may also be dependent to some extent upon fettling problems. Steel castings present no difficulty since oxy-acetylene cutting methods are applicable to any normal thickness of steel. Heavy

castings in cast iron, copper-base alloys, or nickel-base alloys are more difficult to fettle. The atmospheric head developed for steel castings by Taylor and Rominski can be successfully applied also in the production of aluminium bronze, Monel and Inconel type castings, since the metallurgical characteristics of these alloys are suitable : these heads can be more easily removed than can the more orthodox feeders. The Connor runner, which was a British development, is an effective means of gating and feeding : it finds application in the production of grey and alloy cast iron components, and can be easily removed from the castings concerned. Many years have passed since the Washburn core was first applied in steel foundry practice, and this extremely efficient feeding technique continues to be popular in general foundry work, since the fettling operation is also facilitated. Pencil gating and shower gating methods are widely used for similar reasons.

If any given shaped casting design is examined carefully, it will be seen that several alternative running and feeding methods are possible. It is likely that castings of satisfactory quality can be produced by any of the techniques considered, and the final choice may be influenced by other factors. An infinite range of moulding box designs and sizes is available for casting production, yet all foundries find it economical to standardise their production with a comparatively limited number of box sizes and designs. Special boxes are made where these can reduce production costs, but in most cases, the casting concerned is made in a stock-size moulding box capable of accommodating the pattern equipment conveniently. There are approximately 4,500 foundries in Britain, and the majority of these are jobbing plants in which the castings produced cover a very wide range of designs. In all cases it is desirable to use the smallest box possible, in order to avoid excessive sand handling and other labour costs. It will readily be seen that running and feeding techniques can be influenced by the size and type of moulding box available in the foundry concerned. The quantity of riser metal provided may be excessive in certain cases, if the box parts provided are unduly deep, since foundry personnel almost invariably fill riser cavities to the limit. A simple casting is illustrated, in which no less than nine different running techniques are possible. It will be appreciated that the average shaped casting is more complex than the example given, and the choice of running methods will probably be no less.

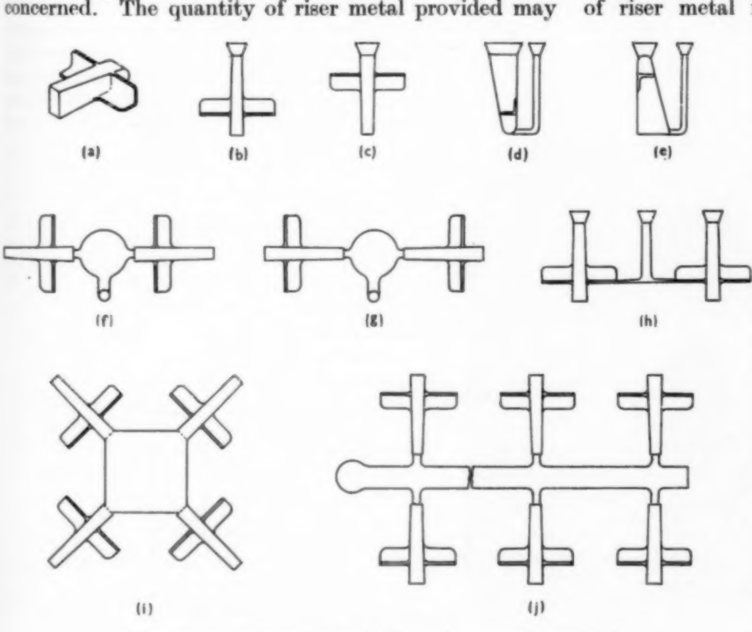


Partial mould reversal technique

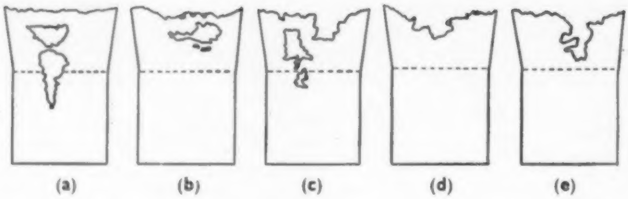
Exothermic Preparations

Casting size and design influence the running method chosen to a marked degree. The steel castings which have been illustrated in previous articles afford excellent examples of the variety of section thicknesses which may be encountered in practice. French workers have established that certain sand castings may be successfully produced by slow pouring methods, the quantity of riser metal required being then much less than normal. Many workers have proposed that exothermic preparations should be added to the risers of sand castings in order to obtain a more favourable yield. Alternatively the risers could be suitably insulated, for the same purpose.

Exothermic preparations are efficient, and much benefit can be derived from their application, particularly to alloys of high shrinkage capacity. Many proprietary mixtures are available, and it is difficult to assess the virtues of each, except experimentally under actual foundry conditions. On one occasion, an 8 in. cube was selected as a pattern, and five sand moulds were made. These were identical in every respect, including running and feeding methods, and all were poured at the same temperature. Three proprietary exothermic compounds were chosen, and a quantity of chopped wheat straw was also prepared. Steel was poured into the moulds concerned, and for control purposes one casting was allowed to



Nine ways of running and feeding a simple casting.



(a) No addition. (b) Chopped Straw.
(c) Mixture A. (d) Mixture B.
(e) Mixture C.

Exothermic feeding compounds applied to the casting of 8 in. cubes.

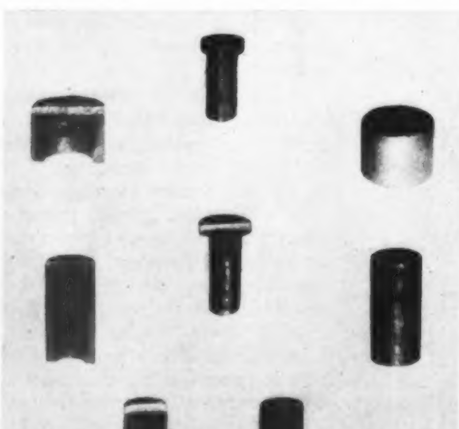
solidify without any addition. One feeding preparation was added to the riser of the remaining castings immediately after pouring was completed. All castings were sectioned vertically when solid, and the extent to which piping had occurred was then apparent. It will be seen from the illustration given that material such as chopped straw can be quite useful as a feeding preparation. It may be that the insulating properties of the ash formed during combustion are as important as the heat generating capacity of the mixture concerned. Any technique which will enable shaped sand castings to be produced with less volume of metal than is now possible will be valuable in the foundry industry. Runner and riser metal is less valuable when fettled than that contained in the casting, yet it is no less expensive to produce.

Chills and Deneseners

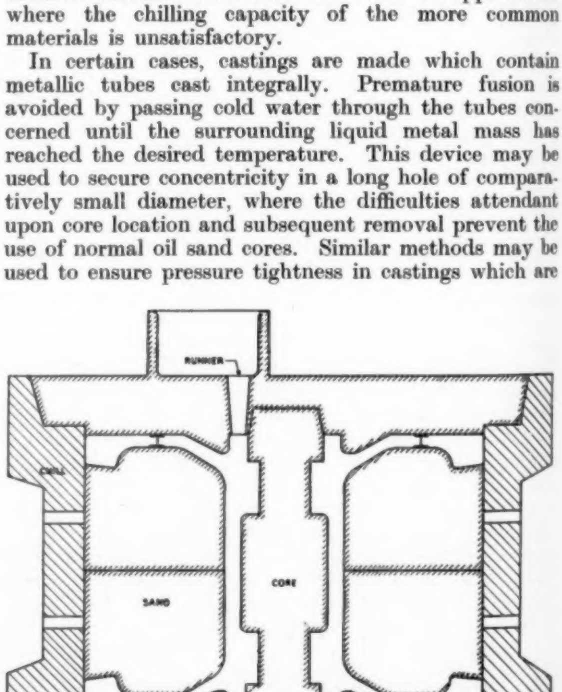
Sand castings may be less sound than those which are produced in metal moulds. Perfect soundness is never obtained, though the castings may be adequate for the purpose intended. Some improvement may be realised if composite moulds are used. Mould assemblies which are partially metallic, simplify the moulding operation, and such moulds are frequently used for the production of chilled castings for abrasion resistant purposes. A typical assembly used for chilled iron castings is illustrated.

Favourable solidification conditions in sand moulds can often be established by the use of chills or denseners. The terms are not usually regarded as synonymous, though they are somewhat loosely used in the industry. Both chills and denseners serve to promote an increased rate of heat abstraction in the mould area to which they are applied. Many foundrymen declare that chills are those inserts which can be recovered from the sand mould after use, while denseners cannot be recovered, since they become fused into the casting concerned. Others believe that chills can be distinguished from denseners in that the former produce a definite change in the microstructure of the casting concerned. In such cases, grey iron castings are obtained which are white or mottled in appropriate places. All bronzes and many light alloys suffer changes of a somewhat similar nature when partially chilled in sand moulds. In contrast, denseners are thought to produce castings of desirable soundness while changes in microstructure are avoided. It is not possible to arrive at a precise definition, since many conflicting features appear if the field is closely examined. For example, in the manufacture of pure copper or aluminium castings, chills *or* denseners may be used, and sounder metal is thereby obtained. Changes in the microstructure are not perceptible, if slight grain refinement be excluded. Chills are usually metallic, and grey cast iron is commonly used for this purpose. Aluminium chills find application in the production of chilled iron tappets for automobile work, and graphite or silicon carbide slabs are sometimes used in applications where the chilling capacity of the more common materials is unsatisfactory.

In certain cases, castings are made which contain metallic tubes cast integrally. Premature fusion is avoided by passing cold water through the tubes concerned until the surrounding liquid metal mass has reached the desired temperature. This device may be used to secure concentricity in a long hole of comparatively small diameter, where the difficulties attendant upon core location and subsequent removal prevent the use of normal oil sand cores. Similar methods may be used to ensure pressure tightness in castings which are



Chilled cast iron tappets for automobile engines.



Sand mould incorporating chills.

Courtesy of Midland Motor Cylinders, Ltd.

Chilled iron camsleeve castings for large diameter camshafts.

Courtesy of Smith & Wellstood Ltd.

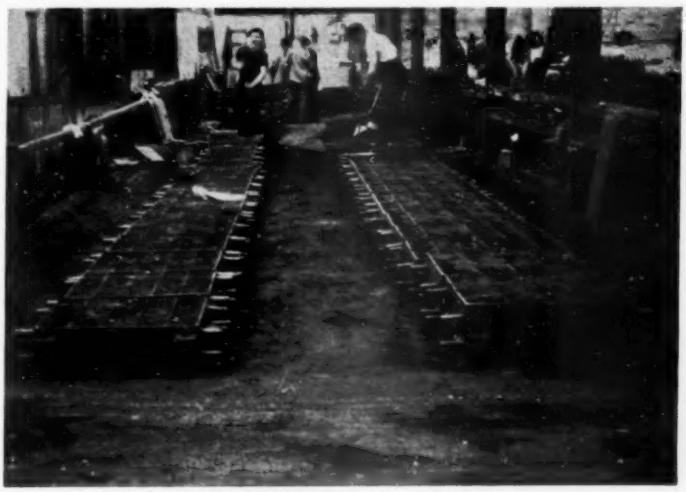
Casting in a mechanised foundry.

themselves intended to be water-cooled in service. There is no doubt in such cases that the appropriate cooling conditions are due to the water cooling technique, and not to the metallic tubes contained in the casting. Dense material will be obtained in the areas adjacent to the tubular inserts, and some change will also be observed in the microstructure, if the alloy involved is susceptible to drastic cooling. It may be said, therefore, that all chills are denseners, but the converse is not always true.

Jobbing and Mechanised Methods

Sand castings can be produced by either jobbing or mechanised methods. The size of the order concerned is normally the deciding factor, and since shaped castings are seldom required in large numbers, jobbing methods predominate in British practice. Less than 80 foundries are responsible for the bulk of British production, and many of these plants specialise in automobile castings, or in the production of castings for domestic applications. A relatively small number of foundries are concerned with the production of cast iron pipes, yet these plants are the largest consumers of pig iron in the foundry industry. Sand casting production is a very skilled business, and the economics of the industry are influenced to a marked degree by the amount of skill, and particularly the speed, displayed by the average moulder. Since skill is at a premium in all branches of industry, it follows that in order to increase casting production, or to reduce production costs, attention must be concentrated upon reducing the amount of skill required, and removing most of the manual effort involved. Various mechanical aids are available for jobbing work, but do not rank as mechanisation, though the latter term cannot be easily defined. When sand moulds are made, either manually or mechanically, the technique used is substantially the same. In each case, the moulding material is consolidated around the pattern, so that the finished mould is true to shape, and is dense enough to support the liquid metal without deformation, yet is sufficiently permeable to facilitate venting. The mass of consolidated sand is generally supported externally by means of a metal or wooden moulding box, though in certain types of light casting production, the box may be removed after the mould is made. Alternatively, the mould assembly may be made in a sand bed of suitable dimensions. Sand moulds may be single, two-part, or multi-part, depending upon casting size and design. Two-part moulds predominate in general practice, and can be conveniently made either by hand or by machine. Multi-part moulds are occasionally made by mechanised methods, but hand moulding techniques are normally used.

The first moulding machine appeared some 150 years ago, and was designed as a screw stripping device. In 1837, Adams produced the first jarring machine, and the



Hand moulding of small castings.

Casting in a large jobbing foundry.

first hand-operated squeeze machine appeared shortly afterwards. These units were suitable only for shallow work of simple designs, and the difficulty involved in ramming and stripping complicated patterns, remained until the turnover units, and the jolting units, designed by Teetor and by Herman respectively, became available. The advent of the air compressor gave the necessary impetus to moulding machine development. The names of Tabor, Pridmore, Beardsley and Piper are well known throughout the industry, and their moulding machines cover an amazing field. Few machines capable of application to all types of castings are available, though great ingenuity has been displayed in the design of special purpose units for the production of sewing machine, lawn mower, radiator and other difficult castings. Pneumatic, hydraulic, mechanical and electrically operated machines are in use, each having desirable features. It is likely that combination type machines of the jolt-squeeze-pattern-draw variety find the widest application for general work. Medium and large moulds are frequently made by sand slinging methods, and such equipment is extremely useful.

Wagon Tipplers for Steelworks

Fraser and Chalmers Engineering Works of The General Electric Co., Ltd., Erith, Kent, are to supply two of their new side discharging weighing type wagon tipplers to the order of the South Durham Iron and Steel Company through Messrs. Ross Engineers Ltd. The tipplers will be of special design for weighing and tipping wagons of 60 tons gross load, but in this instance will handle ore wagons containing a maximum of 31 tons and will have a gross weight not exceeding 45 tons.

The drive for one machine will be provided by an A.C. 85 h.p. 730 r.p.m. totally enclosed fan-cooled slip-ring induction type motor, while the drive for the second machine will be provided by a modified Ward-Leonard system to enable the 110 h.p. 500 r.p.m. D.C. mill-type tippler motor and the Ross wagon haulage motors to be operated from one set.

The tipping action of the machines will be fully automatic and no clamping or binding devices are required for holding the wagon to the rails when in a tipped position. The proposed capacity range of the two machines is that one should discharge a total of 20 wagons per hour equivalent to 490 tons per hour from $24\frac{1}{2}$ ton capacity wagons ; while the other will discharge 32 wagons per hour equivalent to 784 tons per hour from $24\frac{1}{2}$ ton capacity wagon.

The hoisting gear will be electrically controlled and operations are regulated by a series of push button switches covering every phase of the machine's activities. One operator only is required for each machine.

Straightening Press for Steel Tubes

Fielding & Platt, Ltd., of Gloucester, have recently delivered a vertical hydraulic straightening press to the Weldless Steel Tube Co., Ltd. Of the open gap type, it is fully self-contained with direct hydraulic pumping equipment using oil as the pressure medium, and has a main ram power of 200 tons. The main frame is of fabricated steel, and has a table of forged steel machined from the solid. The forged steel main cylinder, again machined from the solid, is fitted with a double-acting ram : this assembly is fitted within the top portion of the main frame. The press is powered by a radial-type hydraulic pump giving a maximum pressure of 2 tons/sq. in. and control is by a piston-type hand-operated valve mounted in the centre of the press within easy reach of the operator.

This press is now being installed at the Weldless Steel Tube Company's works at Wednesfield, Staffs, where it will form part of the finishing department for a new installation manufacturing seamless steel tubes.

London Works for Wickman

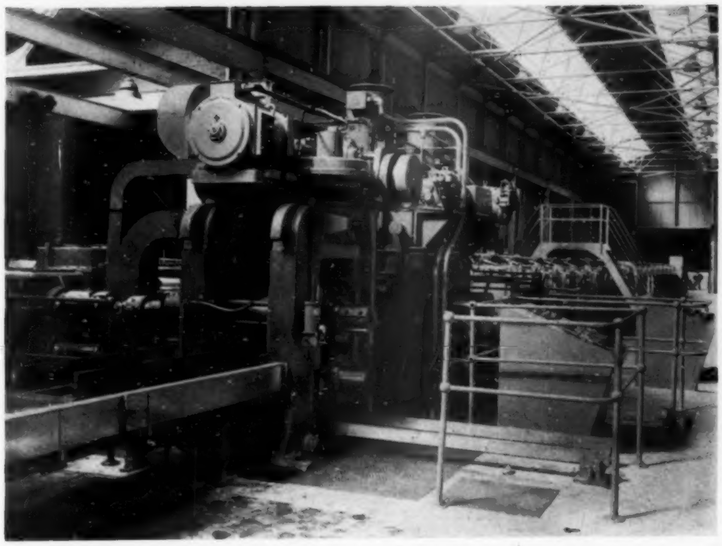
Wickman Ltd. announce the opening of a London branch factory and offices at Oxgate Lane, Cricklewood, N.W.2. The Company's London Area Office, previously at Stratton Street, has been transferred to the new address, where is also now located the Wickman London Export Department. A showroom is being installed in the new premises where machines of the Company's manufacture will be displayed together with many machines of British and Continental manufacture for which the Company are selling agents in the United Kingdom. A production unit is being established in the new premises for the manufacture of Wimet tools, and a separate Electro-Mechanical Department laid down for the production of the Company's high frequency induction heating equipment, Erodomatic electro-erosion machines, and Erodosharp machines for cutting tool reservicing.

Change of Address

The Sales Office of Aluminium Wire and Cable Co., Ltd., is now at 30, Charles II Street, St. James's Square, London, S.W.1. (Telegrams : Aluminiwire, Piccy, London ; Telephone : Trafalgar 6441/6).

Hot Rolling of Steel Strip

Planetary Mill Installed at Willenhall



General view of the mill showing the planishing and planetary stands with the continuous furnace in the background.

A NEW type of mill for the hot rolling of steel strip has been installed by Ductile Steels, Ltd., at Willenhall. It is a Sendzimir hot planetary mill, built under licence by W. H. A. Robertson & Co., Ltd., and is the first mill of its type in operation on a commercial basis outside the United States where, it is understood, there are two non-commercial units and one commercial unit in operation.

The normal means of hot rolling strip are the continuous mill, comprising several stands in tandem, and the reversing hot strip mill, which consists of a reversing stand with hot coilers on either side. The continuous mills are expensive to instal and must, of economic necessity, produce high tonnages, whilst the reversing controls and hot coilers make the reversing hot strip mill an expensive installation. Both these types are, therefore, unsuitable for the smaller producer. On the other hand, even large producers are prone to discourage the production of strip in small quantities, or of special analysis, on account of the high cost of production of small lots. Thus, for small and large producers alike, there is scope for a hot mill of a versatile nature and relatively low cost.

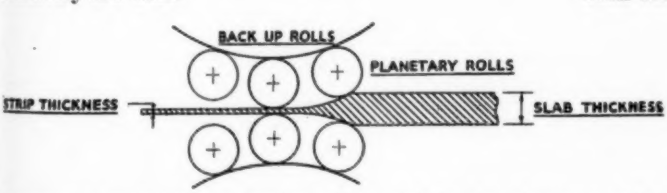
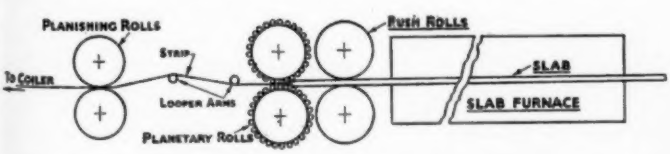


Diagram showing the reduction of the slab in the planetary rolls.

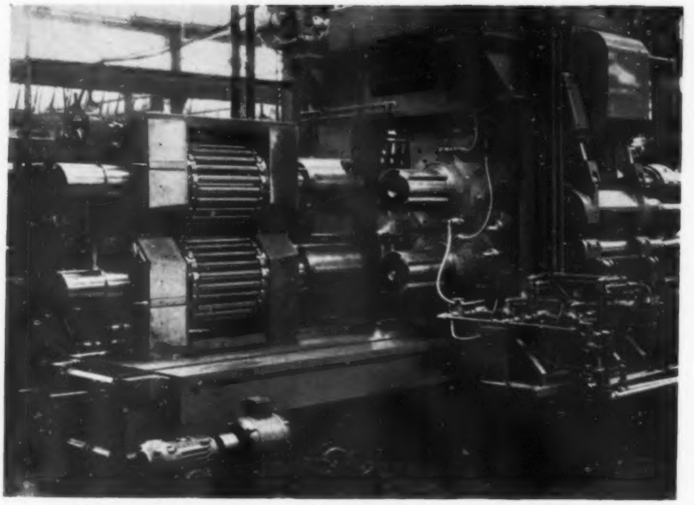


Schematic arrangement of the planetary mill from furnace to coiler.

Planetary Stand

In conventional rolling, the reduction of slabs of, say, 2–3 in. thickness to strip of, say, 0·060 in., requires a number of individual passes. The planetary mill, on the other hand, employs a multiplicity of work rolls in one stand, unites the many passes into one major pass, and thus effects the complete reduction from slab to strip in one pass through one single stand. In the Ductile Steels installation, 26 2 in. diameter work rolls are arranged in equal spacing around the periphery of a pair of 20 in. diameter back-up rolls, and two of these planetary assemblies are mounted one on top of the other in two-high fashion. The work rolls are held in position on the backing rolls by means of cages, and the cages and work rolls are free to rotate about the backing rolls, and are geared together to ensure appropriate alignment and synchronisation. The back-up rolls are driven by a 900 h.p. English Electric motor with a constant speed of 500 r.p.m. The drive is transmitted through a pinion stand connected by universal spindles to the backing rolls, and the power is transferred to the work roll by frictional contact with the backing rolls and the metal being rolled. The speed of rotation of the 2 in. work rolls is approximately 3,000 r.p.m. When wear makes a roll change necessary, the complete planetary back-up roll assembly can be withdrawn sideways and replaced by another which has been built up in readiness.

Due to the extremely large roll bite angle and the nature of the work roll mounting, the slabs must be forced into the rolls, and this is accomplished by 22 in. diameter pinch or feed rolls mounted in the same housing as the planetary assemblies. The pinch rolls make an initial reduction and push the slab through the planetary rolls at a selected speed, according to the finishing gauge. These rolls are driven by a 30 h.p. English Electric motor and the speed range varies



The planetary stand with planetary rolls withdrawn.

from 4·5 to 9 ft./min. The slab speed is relatively low whilst the planetary rolls are driven at a much greater speed. Thus, a small section of slab is fed to each passing work roll and, since it is not free to back up, the passing pair of work rolls roll out a short length of strip. The combined action of the many rolls as they pass over the slowly moving slab thus produces a continuous strip. This is a continuous process, and it is vitally important that as soon as one length of slab is rolled, another must immediately follow on, fed by the pinch rolls, to push the end of the preceding slab through the planetary rolls.

Planishing Stand

Immediately following the planetary mill, the two-high planishing mill is installed, so that a further reduction can be made to obtain thin gauges and a perfect hot-rolled finish. The planishing rolls are driven by a 200 h.p. English Electric motor with a variable speed of 14 to 43 r.p.m. In order to regulate the strip tension to the correct value, a conventional looper arm is fitted between the planetary and planishing stands. The push roll, planetary roll and planishing roll adjustments are carried out by the conventional type of electrically-operated screwdown gears, and the motion measured on a Selson drive, one to each screwdown mechanism.

Continuous Furnace

By employing pinch rolls as feed rolls, slabs of any length may be rolled, and this length is not limited by stand spacing, since one mill stand only is involved. Again, since the progress of the slab through the mill is relatively slow, the operation lends itself to progressive heating of the slab. Thus the heating furnace is placed immediately adjacent to, and in tandem with, the mill itself, and as the slab is brought up to rolling temperature it passes directly into the mill and is rolled to strip. The furnace which was designed and built by Ductile Steels, Ltd., consists of a number of small separate oil-fired furnace units, placed end to end. The slabs are butt-welded and conveyed through the series of furnace units by water-cooled rolls. The varying heat input requirements for different steels, sizes of slab, etc., are controlled by the number of furnace units used and the speed of travelling through the furnace into the planetary mill at the desired speed of rolling. The furnace is controlled by Ether electronic equipment. With continuous operation, the furnace, the mill elements and the heated slab all stabilise in temperature very quickly, and as a result an exceptionally uniform product, both physically and metallurgically, is produced. Should any particular heating unit collapse or require repairs, it can immediately be removed and a spare one put in its place, thus obviating loss of production which may arise with a large batch type furnace.

Operating Features

All plastic reduction is effected under all-sided compression—vertical pressure of the planetary rolls plus the horizontal pressure of the feeding mechanism. One result of this is that even metals which are distinctly hot-short can be produced without cracks. On a pilot mill in the United States, a wide range of materials has been rolled successfully.

Since the energy of plastic deformation is spent within a small fraction of a second on a short piece of metal within the roll bite, the finished strip is hotter at the exit from the roll than the entering slab : the temperature rise is of the order of 50° C. This factor, coupled with the fact that the small work rolls have a high penetrative power, makes it possible to roll metal at a relatively low temperature, and reduces considerably the scale hazard.

The mill has been designed to produce 10 tons per hour of strip in widths ranging from 6 in. to 15 in., and gauges from 0·187 to 0·040 in. Ductile Steels have, however, shown that this figure can be gradually increased. The gauges are exceedingly accurate and experience has shown that a 30 ft. slab rolled into a coil does not vary more that 0·002 in. in thickness from end to end of the coil and across the width of the strip. It is doubtful if this accuracy could be obtained in any other type of hot mill. Ductile Steels intend in the near future to roll not only low carbon steel, but a range of carbons up to 1%, stainless steel, silicon iron and alloy steels, which can be rolled as easily in this type of mill as low carbon steel, and which can be produced in much thinner gauges than on the conventional type of mill (0·040 in. as against 0·125 in.).

Future Developments

The capital and running costs of the planetary mill are comparatively low, and the floor space and number of operators required are also less. It is interesting to note that the present installation is manned by operators who have not had previous experience of rolling.

Among the advantages of the planetary mill is the fact that it produces strips of certain widths and gauges that cannot be rolled at all on some types of mill and would be uneconomical to roll on others. Furthermore, small tonnages of a particular gauge and width can be produced without any loss of time.

It appears, therefore, that for certain classes of work the planetary mill is a most promising development, and it is of interest to note that a mill of this type is being made for the production of 20 in. wide strip in Canada, whilst U.S. developments include two 40 in. wide mills.

Light Alloy Bascule Bridge

THE new bridges at the entrance to the Victoria Dock, Aberdeen, were officially opened recently by Her Majesty Queen Elizabeth, the Queen Mother.

They consist of a bascule bridge, employing aluminium alloys in the moving spans, and a steel removable bridge. Although the bridges are of no great size, they represent a pioneering achievement. The bascule bridge of unorthodox design is of an entirely new type, and is the first bascule bridge in Scotland to employ aluminium alloys in its construction. Novel methods of fabrication, of operation and counterbalancing are used in this bridge, which is the subject of a patent by the Aberdeen Harbour Engineer, Mr. John Anderson, M.I.C.E., M.I.Struct,E., M. Inst. T. The bridges form a modern traffic link between the north and south sides of the Victoria Dock. They serve the nearby deep water berth and will greatly facilitate the rapid turn-round of shipping and relieve road congestion elsewhere. The opening ceremony marks the completion of the first stage in the Aberdeen Harbour Commissioners' long term plans for the development of the port. To date, nearly £1,000,000 has been spent on various improvement schemes.

A number of points had to be considered in deciding on the type of movable bridge for the south entrance to the Victoria Dock. As it is the principal commercial dock and communicates with the Upper Dock, the construction of a new movable bridge should not interfere with the passage of shipping through the dock from start to finish of the operations. The limited space available at the site dictated that the bridge should occupy the minimum ground space, and concentrations of weights should be reduced to a minimum so that the foundation costs could be kept low. The bridge must be speedy in operation, driven by simple machinery with low operating costs. It should present a pleasing appearance, if possible, and should be immune from damage by shipping when in the fully open position. In order to meet all these requirements, Mr. John Anderson developed his new type of double leaf heel trunnion bridge employing aluminium alloys in the moving spans. Each moving leaf rotates about a trunnion at the landward end, the trunnions being set at 100-ft. centres.

The contract for the design, construction and erection of the new bridges was entrusted to the Head Wrightson organisation, whose aluminium subsidiary company has had a wide experience in the design and fabrication of the heavier type aluminium alloy structures. It may be recalled that in 1948, Head Wrightson & Co., Ltd., built the first aluminium alloy bascule bridge in the world at the entrance to the Hendon Docks, Sunderland.

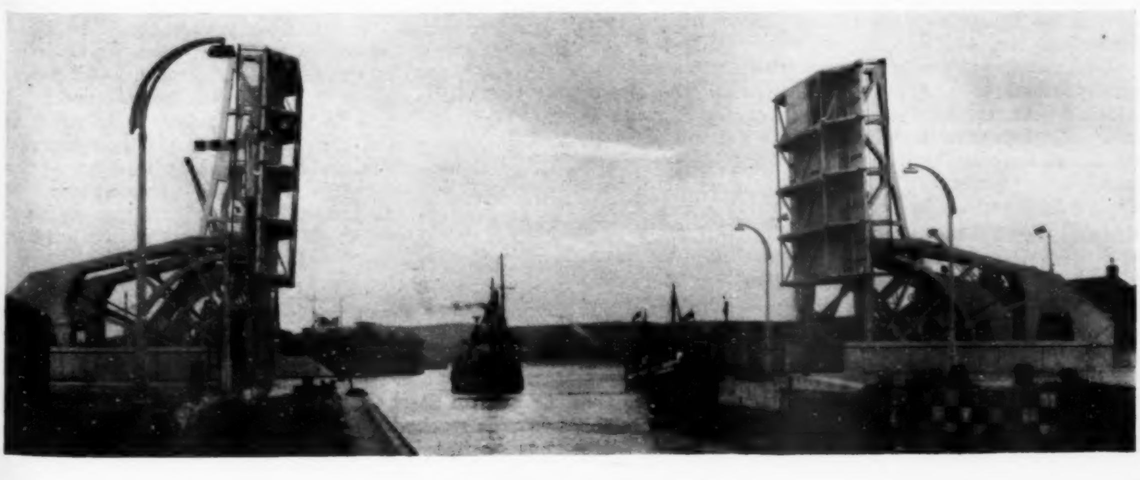
Structural Details

The bridge is of double leaf trunnion type, designed to carry road and rail traffic. A 22 ft. wide roadway is provided between the trusses, whilst outside the trusses walkways 5 ft. wide are provided to cope with the peak hour pedestrian traffic. The total weight of aluminium alloy used in the movable spans is 48 tons. The flooring system employed is that of cross girders carrying troughs, the wells of the troughs being unfilled. To the tops of the troughs are bolted Rhodesian teak underlay timbers, some 3 in. thick tongued and grooved and laid diagonally. The rails of standard gauge are set to one side of the bridge and are bolted through the teak underlay to the tops of the troughs.

Douglas fir dowelled paving blocks 5¼ in. deep form the road surfacing and they are coach screwed to the teak underlay. In the two leaves there are approximately 25½ tons of timber. The principal dimensions of the bridge are :—

Clear opening to dock	70 ft.
Span between centre line of trunnions	100 ft.
Length of moving span	69 ft. 11½ in.
Approximate overall length of bridge	198 ft.
Clear height under machinery portal	16 ft.
Angle of opening of bridge	87°
Overall width of bridge	37 ft. 1 in.
Centre of trusses of moving span	25 ft.

The plates and extruded sections for the bridge were supplied by British Aluminium Co., Ltd. and Northern Aluminium Co., Ltd. Two types of aluminium alloy were used, namely, the aluminium-copper-manganese-magnesium type alloys for the flooring system, and the



aluminium-magnesium-silicon alloys for the main trusses and the main operating machinery portal. These heat treated alloys are designated in the B.S.S.1470 Series as follows, and the mechanical properties are also listed.

Alloy	*Type*	0·1% *Proof Stress* (tons/sq. in.)	*U.T.S.* (tons./sq. in.)	*Elongation* (% on 2 in. gauge length)
HE10WP	Al-Mg-Si	15	18	10
HP10WP	Al-Mg-Si	14	18	8
HE15W	Al-Cu-Mn-Mg	15	25	15
HPC15W	Al-Cu-Mn-Mg	20	26	8

To ensure maximum protection against the acid bearing teak underlay, the whole of the flooring system has been metal sprayed with 99·5% pure aluminium. Throughout the fabrication and erection of the bridge, precautions have been taken to insulate all dissimilar metals to prevent any possible electrolytic action.

An outstanding advance in the technique of aluminium fabrication has been the successful cold driving of large size aluminium alloy rivets, up to ⅞ in. nominal diameter, both in the shops and on site. The rivets have special heads to facilitate their driving. Rivet test pieces driven on the site were subsequently tested at the University of Aberdeen with highly satisfactory results.

The dead weight of each moving leaf is counterbalanced by the use of a fixed amount of counterweight contained in a welded steel box, hanging from a 1¾ in. diameter locked coil rope and passing over a special cam, bolted to the main truss of the moving leaf. The cam provides the necessary variation in "lever arm" to the counterbalance pull, which is required as the moving leaf is being opened or closed. There are two counterbalance weights to each leaf, one to each side of the truss and the counterbalance weights run into suitable pits provided in the rear of the mass concrete foundation as the moving leaf opens. The shore steel fixed structure has an "A" frame at its rear which carries a 7 ft. 6 in. diameter pulley, over which passes the counterbalance weight rope. Each balance box weighs approximately 24 tons, the weight being made up of cast iron blocks suitably bedded in lead.

Operation

All the operating machinery is neatly housed within an aluminium alloy portal girder some 5 ft. square, forming part of the moving leaf. The machinery, driving the bridge up and down, operates on the twin fluidrive system. Two electric motors (13½ h.p. and 10 h.p.) running at different speeds, drive into a differential via fluid couplings and this permits the slower motor to be reversed when a "creeping" speed is required. This twin fluidrive system is a recent development and enables the bridge to operate at a very fast speed or a "creeping" speed, in conjunction with electrical control equipment. When the bridge is fully open, this portal girder forms a further barrier to any road traffic which may have over-run the outer gates. The steel pin type rack quadrant is embodied in the shore fixed structure and forms part of the "operating machinery." The rack, comprising 78 pins positioned to a close tolerance, meshes with a pinion extending from the moving leaf.

The steel fixed structure on the shore performs the dual function of carrying the counterbalance weight pulley and of helping to transmit a portion of the live load on the moving bridge well away from the quay face. The live load is transferred from the moving span via "stop arms" on the trusses, which engage with a stop girder of the shore fixed structure.

When in the down position, the leaves are locked to each other by two robust steel bolts which ensure that the leaves deflect together as a load passes over the bridge. The bolts are driven by a motor through gears and are controlled from the master controller through a limit switch. The longitudinal camber in the movable bridge is 4½ in. between trunnions.

Erection

The shore steel fixed structure was positioned first and subsequently the moving spans were mated on site. The steel and aluminium portions were made in different parts of the Head Wrightson works and the accuracy of the workmanship may be gleaned when it is noted that the moving spans were successfully erected on site in 90 days. A trial erection of the aluminium alloy moving spans at Thornaby enabled the flooring contractors to obtain actual dimensions of the spans and to pre-fabricate the wood decking. The lightness of the aluminium, meant that large pieces could be shipped direct to site and heavy cranage was not required.

Metal Pre-Treatment and Reconditioning Plant

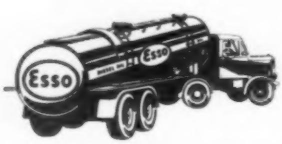
What is believed to be the world's largest metal pre-treatment and reconditioning plant in the world was opened on November 6th at Antwerp, in the presence of official representatives of the three fighting services, the Ministry of Supply, the Belgian Army and the Belgian Ministry of Defence.

The work undertaken in this plant, in the factory of Ets Beherman Demoen S.A. (formerly the Mercedes-Benz plant where the Germans manufactured aero engines during World War II), embraces the treatment of all tracked and wheeled vehicles for the Belgian Army and N.A.T.O. forces. Basically, the plant comprises three immersion tanks into which components are successively dipped. The first, which is 29 ft. × 12 ft. × 9 ft., with a normal working capacity of 16,450 gallons, is used for degreasing and paint stripping by Jenolite P.S. 5 solution. Tanks 2 and 3 are each 30 ft. × 12 ft. × 10 ft., with working capacities of 15,250 gallons, and they are used for heavy scale removal by Jenolite H.S.R. solution, and rust removal, rust proofing and paint bonding by Jenolite R.R.N. (the Jenolizing process). The P.S. 5 tank is steam heated through coils, whereas the other two are heated by means of steam heated water jackets of 5,550 gallons capacity. Between tanks 1 and 2 is a brick pit equipped for power rinsing, in which components are rinsed after degreasing and rust removal. Components are moved from tank to tank by power-operated cranes capable of handling up to 25 tons.

The whole plant has been designed, erected and delivered by Jenolite, Ltd.

English Steel Corporation, Ltd.

Vickers, Ltd. and Cammell Laird & Co. Ltd. have opened conversations with the Iron and Steel Holding and Realisation Agency for the repurchase of interests in English Steel Corporation, Ltd. If and when agreement is reached a further announcement will be made, but it will take some time.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NEWS AND ANNOUNCEMENTS

The United Steel Companies' Fellowship in Metallurgy

THE UNITED STEEL COMPANIES LIMITED announce that they have established a Research Fellowship in Metallurgy in the University of Sheffield and this will be tenable in the Department of Metallurgy.

The object of the Fellowship will be to advance metallurgical knowledge and not to train men for research. The persons to be appointed from time to time will, therefore, be those who have already served their apprenticeship in research and have shown ability to conduct independent investigations. The field of study within which they will be expected to work will be ferrous metallurgy, but this does not exclude the appointment of researchers in refractory matters, knowledge of which is of great importance in ferrous metallurgy.

The Fellowship will be awarded by the Senate of the University. The normal period of tenure will be five years and the Fellow will be appointed initially for two years and then annually; remuneration will be a minimum of £750 for the first year, rising by annual increments of £50. Arrangements for appointing the Fellow are in hand.

The United Steel Companies state that they are establishing the Fellowship since they believe that more research of a fundamental kind into metallurgical problems will be the better for all concerned in the industry. Moreover, this type of research is most suitably undertaken in a University, especially that of Sheffield, which, by reason of its background and location, can offer facilities of a very high order.

Cantor Lectures

THE Cantor Lectures of the Royal Society of Arts will be given this year by Mr. G. L. Bailey, Director of The British Non-Ferrous Metals Research Association. The general subject will be "Alloys," and in the first lecture on November 23rd he will discuss the structure of metals and alloys; equilibrium diagrams; the deformation of metals; and the properties associated with different structures. The selection of metals and alloys for industrial use will be the theme of the second lecture on November 30th, the subject being divided into the pure metals; alloys for castings; wrought alloys; and the development of strength by heat treatment. The final lecture on December 7th will deal with alloys for resistance to creep at high temperature; corrosion resistant alloys; and general conclusions.

Colombo Plan Trainee from India

MR. NRIPESH CHANDRA BAGCHI, M.Sc., A.Inst.P., Assistant Director in charge of the X-Ray Laboratory of the Government of India's Test House, at Alipore, Calcutta, has arrived in the United Kingdom for training, made available under the Colombo Plan Technical Co-operation scheme, in modern industrial radiographic practice and the use of industrial X-ray plant for testing metal structures which has recently been installed at Alipore.

Mr. Bagchi will spend about five months at various institutions in the United Kingdom. His time is to be divided between Messrs. Solus-Schall Ltd. the Metallurgy Division of British Railways (at Glasgow and Darlington), the Naval Construction Department of the Admiralty at Bath, the National Physical Laboratory at Teddington, the Institute of Physics, Messrs. Babcock and Wilcox, Ltd. at Renfrew, and Messrs. Stewarts and Lloyds, Ltd. at Corby.

Metrovick–B.I.C.C Agreement

METROPOLITAN-VICKERS ELECTRICAL CO. LTD., and British Insulated Callender's Cables, Ltd., announce that as from November 2nd, 1953, arrangements have been made whereby Metropolitan-Vickers will take over the manufacture, sale and servicing of resistance welding and heating machines formerly manufactured by British Insulated Callender's Cables. The new arrangement will add considerably to the already extensive Metrovick range of arc welding and resistance welding equipments by the addition of further models of pedestal spot, slow butt, hand flash butt and automatic flash butt welders; also rivet heaters, resistance brazing machines and wire rope parting machines.

Steel Industry Development

THE Iron and Steel Board, after consultation with the Industry, have published and circulated to iron and steel producers concerned, a Notice requiring them to submit for the Board's consent under Section 6 of the Iron and Steel Act, 1953, any proposals for modernisation or development estimated to cost more than £100,000 and which fall within the scope of the Board's powers under that Section. The Board will from time to time be reviewing this criterion in the light of experience.

G.E.C. Contract for Temper Mills

THE GENERAL ELECTRIC CO., LTD. has been entrusted by The Steel Company of Wales with a contract, valued at £300,000, for the complete electrical equipment for two 42 in. temper mills which are to be installed at the new Velindre Works at Morriston, near Swansea. This order follows the completion of a similar contract for the two temper mills, now in commission, at the Trostre Works, which are the first in this country to operate at strip speeds up to 4,000 ft./min. The new temper mills are being built by The Davy and United Engineering Co., Ltd., of Sheffield, and each will be equipped with two 1,000 h.p. motors for the main stand drives, two 500 h.p. and two 250 h.p. tension roll motors, and two 300 h.p. motors for the uncoiler and reel. The control scheme for these drives will be similar to that adopted for the Trostre plant, and will embody G.E.C. cascade control exciters working in conjunction with electronic amplifiers. McLellan and Partners, the consulting electrical engineers for the Abbey, Margam and Trostre plants of the Steel Company of Wales, are also acting as consultants for the Velindre project.

Modern Traffic Methods Encouraged by British Railways

THE British Transport Commission announce that in order to encourage the transport of traffic on pallets no conveyance charges will be made by British Railways as from Monday, November 2nd, on owners' pallets on which goods are loaded, or for the return of the pallets

to the senders. Traffic conveyed on pallets by goods or passenger train services will be charged on the net weight of the goods and packing but excluding the weight of the pallets, and returned empty pallets will be carried free by rail back to the point of origin. Following experimental transits by railway arranged in conjunction with large firms, 72 additional pallet vans are being built to cater for regular flows of traffic.

Metal Restrictions Removed

All restrictions on the use of nickel have been removed by the Board of Trade and the Ministry of Supply with effect from 6th November, 1953. The revoking Orders, the Nickel Prohibited Uses (Board of Trade) (Revocation) Order, 1953, S.I. 1953 No. 1605 and the Nickel Prohibited Uses (Minister of Supply) (Revocation) Order, 1953, S.I. 1953 No. 1607 are on sale at H.M. Stationery Office. The Minister of Supply has withdrawn the Alloy Steel Directions restricting the use of nickel in the manufacture of alloy steels. This follows similar action taken recently with regard to molybdenum.

New President of British Standards Institution

At the Annual General Meeting of the British Standards Institution held on Thursday, October 29th, at British Standards House, 2, Park Street, W.1., Sir Roger Duncalfe was elected President to succeed Viscount Waverley. Sir Roger's appointment was proposed by Lord Waverley, whose three-year term of office had ended in accordance with the B.S.I. constitution.

Sir Roger Duncalfe, as Chairman of British Glues & Chemicals Ltd., is a leader of Britain's chemical industry, and has been closely identified with standards work and the B.S.I. for more than twenty years. He has been successively Chairman of Technical Committees engaged on standards projects, Chairman of the Chemical Divisional Council and of the Institution's Finance Committee and General Council, and more recently its Vice-President. He was knighted for his outstanding contributions to industrial standardization at the time of the B.S.I. Golden Jubilee in 1951.

Although he has devoted so much time and energy to this specialized activity, Sir Roger has also undertaken much work in other directions on behalf of industry. He is President of his own industry's organization, the Federation of Gelatine & Glue Manufacturers; past Chairman and Vice-President of the Association of British Chemical Manufacturers; and his long service to the Federation of British Industries is marked by the fact that he holds the office of Vice-President, and is also Chairman of the Federation's Technical Legislation Committee.

Change of Address

The transfer of the Newton Victor's Head Office and London Area Branch Office establishments to larger premises at 132, Long Acre, London, W.C.2. is now completed. The move brings together again under one roof the various departments and activities formerly divided between the offices at Cavendish Place and Bolsover House and, it is believed, will make for improved efficiency and greater convenience for the Company's customers, correspondents and suppliers.

Personal News

Northern Aluminium Co., Ltd., announce the following changes in their Sales Department: Mr. F. Layton is to take charge of the Sales Administration Department at Banbury, being succeeded as Manager of the Leeds Area Sales Office by Mr. H. M. Louch. Mr. Louch's previous position as Sales Development Manager is to be held by Mr. E. D. Iliff, at present Publicity Manager, and the Publicity Division will be in the charge of Mr. R. F. Tayler. These new appointments became operative from 1st November, 1953.

The Rt. Hon. The Earl of Dudley has retired from the Board of British Iron & Steel Corporation Ltd., of which he had been Chairman since its inception in 1935, following the purchase of Round Oak Steel Works, Ltd., by Tube Investments, Ltd. Sir Charles Bruce-Gardner, has been appointed Chairman of the Board. Sir Charles is Chairman of John Lysaght, Ltd.. Director of the Steel Company of Wales, Ltd., Guest Keen & Nettlefolds, Ltd., and of several other important industrial companies.

Mr. M. W. Shorter, a Director and the General Sales Manager of Westinghouse Brake & Signal Co., Ltd., has been appointed Managing Director of the Company.

Following the acquisition of complete control of their Associated Company, Foundry Services Incorporated, of New York, Mr. Weiss, Managing Director of Foundry Services Ltd., of Birmingham has gone to America for two months to assist in the drive for increased dollar earnings.

Regent Oil Co., Ltd., announces the appointment of Mr. Beresford Clark as Sales Manager, Lubricants. Mr. Beresford Clark was previously Manager, Marine Sales. In his new appointment, in addition to marine business, he will also be in charge of automotive and industrial oil sales in the United Kingdom.

Mr. D. C. G. Lees has left The Aluminium Development Association to join Aluminium Union Ltd., as Development Engineer. Mr. Lees was a Research Investigator with the British Non-Ferrous Metals Research Association from 1940 to 1946, after which he was for two years on the staff of Industrial Newspapers Ltd. He joined The Aluminium Development Association in 1948.

The Hon. R. A. Balfour has joined the Board of High Speed Steel Alloys, Ltd.

Mr. R. B. Potter has joined the Board of Davy and United Engineering Co., Ltd. Mr. Potter is Chairman of Simon-Carves, Ltd.

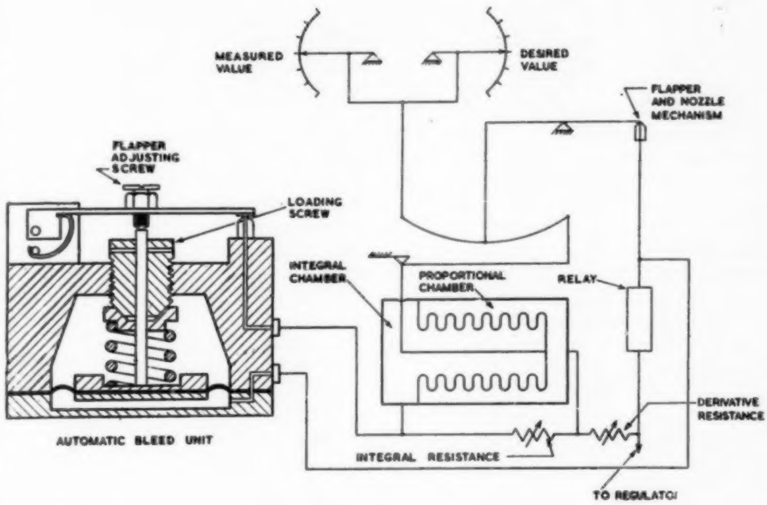
Mr. R. H. Hall has joined Foundry Services, Ltd., to act as a Technical Representative in part of the Yorkshire area. Mr. Hall was formerly a Metallurgist with Northern Aluminium Co., Ltd., Rogerstone.

Mr. R. C. Edmonds of Foundry Services, Ltd., delivered a paper—of which he is the co-author with Dr. D. V. Atterton, also of Foundry Services—on "The Exothermic Feeding of Castings" to the Eastern Canada Chapter of the American Foundryman's Society at their last meeting. Mr. Edmonds, who has been closely connected with the works and laboratory control in the manufacture of Feedex exothermic feeding compound in this country is staying on in Canada for the next few months to assist Foundry Services (Canada), Limited in the manufacture and sales of Feedex in that country.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Kent Automatic Bleed Unit



Conventional automatic controllers employing integral action may have some disadvantages when used on discontinuous or batch processes. An " overshoot " of the measured variable tends to occur when the variable returns to its desired value after an interruption of the process.

The integral function of a controller is constantly in operation while the measured variable deviates from the desired value; in consequence, if there is a prolonged interruption of the process, the integral action will build up until it reaches its limit, when it will become " saturated " and render the controller mechanism ineffective. In air-operated controllers this " saturation " occurs when the integral chamber pressure reaches its maximum, and the deviation will then cause the flapper (of the controller detecting mechanism, normally a flapper and nozzle) to be held outside its normal working range. The flapper does not re-enter its normal working range until the deviation is eliminated, the plant regulator meanwhile being at the limit of its travel. When plant conditions return to normal and the measured variable rises in response to the plant regulator position, the controller is therefore unable to produce any corrective action until the measured variable has reached the desired value. An " overshoot " of the measured variable may therefore take place and possibly result in damage to the plant or impair the operation of the process. In order to eliminate this " overshoot," a device has been developed by George Kent, Ltd., known as the Automatic Bleed Unit.

This unit is connected to the integral chamber of the controller and the controller nozzle line, so that when an interruption of the process occurs and the control pressure reaches its maximum, a " bleed " of air from the integral chamber takes place, thus retaining the flapper within its normal wording range and keeping the controller mechanism effective. This action will occur continuously until plant conditions return to normal. In consequence, control action begins while the measured variable is returning to its desired value, thereby greatly reducing the possibility of " overshoot."

The Automatic Bleed Unit consists essentially of a cast body enclosing a flexible diaphragm. This diaphragm is constrained by an adjustable control spring, as shown in the illustration. When the control pressure, which is applied below the flexible diaphragm, reaches its normal maximum and overcomes the control spring, the pivoted arm is raised, opening the nozzle valve connected to the integral chamber of the controller, and bleeding air from the integral chamber to atmosphere. The control spring is adjusted to correspond with the upper limit of the control pressure range by means of the loading screw at the top of the cast body.

The Automatic Bleed Unit has been successfully employed in practice on control circuits for processes of the discontinuous type, including the control of open-hearth-furnace roof temperature. In this application the periodic furnace reversals result in a temporary fall in roof temperature, which is of sufficient magnitude in many cases to cause severe " overshoot " on the return to normal operating conditions, if an Automatic Bleed Unit is not employed in the control circuit. Such " overshoot " could in time jeopardize the safety of the furnace, by causing melting of the refractories in the roof. Another example of " overshoot " elimination by this means is in automatic superheat control of boilers.

The Automatic Bleed Unit is a simple and reliable device which can be easily added to the standard Kent Mark 20 controller. It in no way detracts from the performance of the controller, nor modifies its response characteristics.

George Kent, Ltd., Luton.

Corrosion Protective

It has long been recognised that zinc coatings are very effective for the protection of iron and steel against corrosion, but the better known methods of applying them, such as hot galvanising and electroplating, are, in the main, only suitable for the treatment of factory produced articles of limited size. A recent attempt to overcome these limitations has resulted in the development of Cowanite which is described as depositing a pure zinc and latex coating for the protection of iron and steel. It is supplied as a solution comprising pure zinc, carbon, latex and carrying agents which evaporate rapidly leaving an adherent film which is touch dry within 14 minutes and hard dry within 40 minutes. It

can be applied by brushing or spraying and has the covering capacity of a good class paint. It can be used as a primer for synthetic and oil-bound paints, but bituminous paints and enamels should not be used over it.

One of the advantages claimed is that, whereas hot galvanising and electroplating require a clean surface, Cowanite can be applied over adherent rust, mill scale and old paints, providing loose oxides and loose flakes of paint have been removed.

Cowanite (Anti-Corrosive), Ltd., 15, Tithebarn Street, Liverpool, 2.

Furane Resins

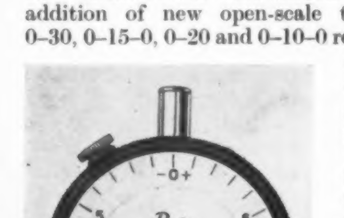
Leicester, Lovell & Co., Ltd., manufacturers of casein synthetic resins and casein glues, announce that they are now in a position to supply a range of furane resins, marketed under the name Cascote. The furane resins show outstanding resistance to weak and strong acids, alkalis and solvents; their hard and durable suface makes them exceptionally resistant to erosion and abrasion; and their resistance to high temperatures is extremely good, being surpassed amongst thermosetting plastics only by the silicones. Particular advantages claimed for the Cascote furane resins are their long storage lives; the fact that they do not suffer from the exotherm usually associated with furane resins; and their improved adhesion to metal. The range includes materials which will harden at both room and elevated temperatures.

The properties detailed above have a considerable appeal in many fields of industry, and particularly for such applications as chemical plant coatings, impregnation of Dufaylite, protective surface coatings, heat-resistant glass fibre laminates, etc. Further information and samples can be obtained from the technical sales manager.

Leicester, Lovell & Co. Ltd., North Baddesley, Southampton.

Dial Indicators

The $2\frac{1}{4}$ in., 3 in. and $4\frac{7}{16}$ in. diameter range of Baty dial indicators has been increased to 42 models with the addition of new open-scale types. Graduations of 0–30, 0–15–0, 0–20 and 0–10–0 reading in either 0·001 in. or 0·0005 in. are now available. These fill the gap between the magnification factor of dial indicators reading 0·001 in. or 0·0005 in. with the common graduations as previously supplied, and the magnification of those reading 0·0001 in. They are particularly useful for batch inspection not demanding indicators reading 0·0001 in., where an easily read scale with widely spaced divisions helps to reduce error and fatigue. The clear open scale of the 0–15–0 graduation is seen in the illustration.



$2\frac{1}{4}$ in. dial indicator graduated 0–15–0 in 0·001 in.

Further additions to the Baty range are a complete new series of $1\frac{11}{16}$ in. diameter dial indicators with a large variety of readings and graduations. Besides the common graduations in the 0·001 in. and 0·0005 in. types, new open-scale versions in both these readings are available. An indicator reading in 0·0001 in. not previously made in this size, completes the range.

Another model has been introduced into the range of magnetic bases made by this company. This has particularly robust arms and clamps especially suitable for use with $2\frac{1}{4}$ in. diameter indicators.

J. E. Baty & Co. Ltd., 39, Victoria Street, London, S.W.1.

Radiographic Exposure Calculator

The British Steel Castings Research Association has recently developed a radiographic exposure calculator for use with the isotopes Cobalt 60 and Iridium 192, materials which are now commonly employed for industrial radiographic purposes in steel foundries and elsewhere. The calculator can also be used in conjunction with radium or radon, and scales are included which permit allowances to be made for the relatively rapid decay of radon and iridium sources. The calculator will fill a long-felt want for a rapid and reliable means of ascertaining radiographic exposure times, when using the artificially prepared radiographic sources in particular, and the following description may therefore be of interest.

The calculator is in the form of a plastic pocket-size slide rule and consists essentially of two fixed scales and two sliding scales, the bottom one of which is locked in a position determined by the type of film in use and the film density required. This position is determined by setting the appropriate density index mark on the bottom fixed scale against a " film factor " on the bottom movable scale. In routine work this setting will not normally be disturbed, unless for any reason the type of film in use is changed, so that the majority of exposure calculations will be carried out by appropriate setting of the upper movable scale only. This scale is reversible, the side employed being determined by the isotope in use. Its setting correlates the four variables, source strength, source to film distance, steel thickness and exposure time.

The setting of the rule may be adjusted to the film density requirement of the user, and includes scales for calculation of radon and iridium decay as well as one which gives the thickness of steel which, for the purpose of setting the rule, may be employed when examining materials other than steel.

Prototypes of this calculator have been subject to practical trial in the laboratories of members of the B.S.C.R.A.'s Non-destructive Testing Panel, and in the light of their observations, production models of the calculator are to be appropriately modified. Assistance in the provision of experimental data was also given by Members of the Panel, and in particular by the Armament Research Establishment of the Ministry of Supply.

The B.S.C.R.A. Exposure Calculator is clearly of interest in industries other than steel-founding, and it is now in course of manufacture in sufficient quantity to render it available outside the membership of the Association, at a price of six guineas.

The British Steel Castings Research Association, Broomgrove Lodge, Broomgrove Road, Sheffield, 10.

CURRENT LITERATURE

Book Notices

COPPER AND BRASS PRESSINGS

C.D.A. Publication No. 26. 80 pp., numerous illustrations. Copper Development Association, Kendals Hall, Radlett, Herts. Free on Application.

Copper and copper alloys are extensively used for general presswork and other metal working operations chiefly because they combine in a unique manner overall low costs with excellent working properties, good mechanical strength and resistance to corrosion. Moreover, in strip and sheet forms, copper alloys may be obtained with close dimensional tolerances and possessing a very good surface finish, so that they are particularly suitable for repetition presswork and other operations which necessitate careful attention to these factors. Additional advantages result from their ' choice ' when polishing and plating are subsequently to be performed, for they can be plated easily and cheaply and are, in fact, ideal material for this purpose.

The C.D.A. Publication No. 26, " Brass Pressings," has been thoroughly revised and brought up-to-date, and is now issued under the new title of " Copper and Brass Pressings and other Products Cold Formed from Strip and Sheet," which expresses the scope of the text matter, much of which is new. It is difficult to describe adequately the wide range of products obtained from copper alloy sheet and strip but photographs of typical examples are included, and information is given on some of the more fundamental of the many different working processes used with these alloys. These include shearing, cupping, redrawing, miscellaneous pressing operations, expanding and contracting, bending and folding, coining, forming by flexible tools, spinning, other metal working operations, joining, heat treatment and pickling.

A further section of the book gives a general description of the type and properties of copper alloys in strip and sheet forms. Although a wide range of these alloys is employed for the manufacture of various products, by far the most widely used materials are the brasses or copper contents ranging from 63% to 70%. Apart from copper, gilding metal and the brasses, the alloys dealt with include tin and phosphor bronzes, nickel silvers, cupro-nickels, aluminium bronzes, silicon bronzes and beryllium-copper.

The book includes a bibliography and index, both of which add to its usefulness as a text book and a work of reference.

PERIODICALS AND SERIALS; THEIR TREATMENT IN SPECIAL LIBRARIES

By D. Grenfell. Published by the Association of Special Libraries and Information Bureau, 4, Palace Gate, London, W.8. 12s. 6d. (by post 13s.).

THE literary, scientific or technical periodical has come to stay—more, it has won such an honoured place amongst the tools of research that it has attained the right to be treated *sui generis*, and not as a poor relation of the book. It is probable that periodicals have been the delight of scholars and the bane of housewives ever since they were first invented. The scholar appreciates a medium of publication that enables him to keep in touch with work in progress in his own and allied fields which is still in the formative, living stage; the housewife on the other hand, gets fed up with what to her are just ' magazines ' of many sizes, too limp to be arranged tidily on book-shelves, and with covers that get torn and dirty.

The librarian, information officer or research-worker may be forgiven if he sometimes shares the prejudice of the housewife, for these paper publications, easily torn and mislaid, and having separate indexes—dog-eared sheets that are in perpetual danger of being swept away as rubbish—can indeed, if they are allowed to, become a nuisance. Mr. David Grenfell, who is Chief Cataloguer at the National Film Library and a past information officer at Aslib, has had a lot to do with periodicals and knows how to handle them. He has experienced the problem they can present in both libraries and information departments, and from this experience has compiled an instructive manual. All concerned with these vital sources of information will find this handbook useful, whether they are experienced custodians or beginners. The acquisition of periodicals, their accession, circulation, arrangement, cataloguing and disposal are all covered in this work.

Trade Publications

THE requirements of modern industrial radiology are extremely varied, and can only be met adequately by a comprehensive range of X-ray films and screens. For example, the critical X-ray examination of magnesium and aluminium alloys demands a fine-grained high contrast emulsion suitable for direct exposure to X-rays, whereas thick steel welds usually require a combination consisting of a faster type of film and either lead screens or salt screens. A booklet recently issued by Ilford Ltd., Ilford, London, provides the industrial radiologist with the technical information necessary to enable him to select the best films and screens for any given X-ray examination, and to use the combination chosen to the best advantage.

WITH the title " Marine Construction," T.I. Aluminium, Ltd., Tyseley, Birmingham, have just published an illustrated brochure dealing with the application of aluminium alloys in shipbuilding and other marine applications. Light alloys provide shipbuiiders with materials which combine light weight for equivalent strength, and high resistance to corrosion, with ease of formability and fabrication. Particulars of T.I. Marine Alloys to meet Lloyds requirements are given, together with other recommended for marine applications not covered by Lloyds structural requirements.

WE have received from W. H. A. Robertson & Co. Ltd., Bedford, a publication dealing with four-high rolling mills. Robertsons have been building this type of mill since 1928, and it is, therefore, only possible to show a relatively few examples of the many types regularly built. Nevertheless, there are examples of hot and cold mills, sheet and strip mills, reversing and non-reversing mills, and mills for ferrous and non-ferrous metals. The examples chosen also feature a range of auxiliary equipment to meet special requirements.

METHODS of glazing the control platforms of steel rolling mills with " Armourplate " glass are illustrated in a new 20-page booklet "The Place of Glass in Industry" issued by Pilkington Brothers, Ltd. Dramatic photographs show marks on the glass made by flying hot

scale, etc. Ordinary glass would, of course, shatter under similar treatment. It is pointed out that in the unlikely event of the glass being broken, there is no danger of injury from flying glass splinters, since "Armourplate," if broken, always shatters into small, harmless, blunt-edged particles. The booklet shows examples of the use of glass in some twenty different industries.

MANY industries produce large quantities of dust in their manufacturing processes. Apart from its possible value, uncontrolled dust of any kind is liable to affect adversely the health of workers, to cause unnecessary wear and tear of machinery, and to become a nuisance to surrounding properties. The problems of dust collection in general are discussed in the first part of the latest edition of "Modern Dust Collection and Fume Removal," numerous examples being given of the application to various industries of plant made by The Visco Engineering Co., Ltd., Croydon. The second part of the booklet deals with the removal of noxious fumes on the same lines, the applications including arc melting furnaces and hot rolling mills for light alloys.

COMPANION booklets recently issued by Ilford, Ltd., deal, respectively, with materials and equipment for use in the Ilford Ozoflex process. This process is designed for the economical and rapid reproduction of drawings, specifications and documents of all kinds. The main advantages of the Ozoflex method are that neither darkroom nor drying facilities are required, and first-class results can be obtained without the need for specialised knowledge to operate the equipment.

A NEW mercury-in-steel air operated transmitter for the distant indication, recording and control of temperatures up to 650° C. is featured in the latest Negretti and Zambra leaflet. It employs the force balance principle, requires a compressed air supply at 20 lb./sq. in., and has a consumption of $\frac{1}{4}$ cu. ft./min. The force balance principle needs only a maximum movement of 0·002 in. of the Bourdon tube, thus ensuring freedom from fatigue and a long, accurate life.

THE current issue of "Wiggin Nickel Alloys" (No. 22) contains a description of a foundry for the precision casting of Nimonic alloys; an article on the use of Monel in the manufacture of squirrel cage rotors and slip rings for electric motors; and details of fine bore tubing in nickel and high-nickel alloys. The application of Inconel in a submerged combustion device is next described and the issue concludes with reference to Nimonic 80 as an exhaust valve material, and to the fusion cutting of high-nickel alloys. Copies may be obtained from Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham, 16.

The first issue of a technical bulletin entitled "Mechanised Welding News" has been produced by Fusarc, Ltd., of Gateshead-on-Tyne, the manufacturers of Fusarc and Unionmelt automatic welding equipment. This publication, which will appear periodically, replaces the production news sheets hitherto put out by this firm. In the earlier news sheets, the aim was to describe the 'case history' of an actual production problem and to show how mechanised welding equipment was adapted to suit each individual case. The new bulletin allows more space for these items and also includes technical descriptions of equipment and many items of interest to those concerned with automatic welding, covering both the visible and submerged arc welding fields.

A LIST of products made by The General Electric Co., Ltd., and its associated manufacturing companies, has been published recently to help buyers of electrical and mechanical equipment who do not know the full range of the Company's manufacturing resources. It is a list of products, not a catalogue, but reference is made to the G.E.C. catalogue sections in which certain products are described.

Books Received

"Congrès des Matériaux Resistant à Chaud" (A.E.R.A. 1951). 408 pp. inc. numerous illustrations. Saint-Germain-En-Laye, 1953. Editions Metaux. 5,000 francs.

"Semaine D'Etude de la Physique des Métaux," 1951. 188 pp. inc. numerous illustrations. Saint-Germain-En-Laye, 1953. Editions Métaux. 1,500 francs.

* "Refractory Hard Metals—Borides, Carbides, Nitrides, and Silicides." By Dr. Paul Schwarzkopf and Dr. Richard Keiffer, in collaboration with Dr. Werner Leszynski and Dr. Fritz Benesovsky. 447 pp. inc. author and subject indexes and numerous illustrations. New York, 1953. The MacMillan Company. $10.00.

* "Hartstoffe und Hartmetalle." By Dr. phil. nat. R. Kieffer and Dr. Ing. P. Schwartzkopf in collaboration with Dr. Ing. F. Benesovsky and Dr. phil. nat. W. W. Leszynski. 717 pp. inc. name and subject indexes, and 280 illustrations. Wien, 1953. Springer-Verlag. Ganzleinen. $19.

"Electric Resistance Heating." Electricity and Productivity Series No. 5. 180 pp. inc. numerous illustrations. London, 1953. British Electrical Development Association. 9s. post free.

"Cast Bronze." By Harold J. Roast, F.I.M., F.C.S., M.E.I.C. 458 pp. inc. numerous illustrations. Ohio, 1953. The American Society for Metals. $4.00.

"Crystal Growth and Dislocations." By Ajit Ram Verma, M.Sc., Ph.D. 182 pp. inc. numerous illustrations. London, 1953. Butterworths Scientific Publications. 30s. net. By post 8d. extra.

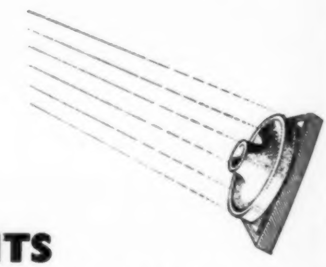
"History of Strength of Materials" (with a brief account of the history of theory of elasticity and theory of structures). By Stephen P. Timoshenko. 542 pp. inc. name and subject indexes and numerous illustrations. New York, Toronto and London, 1953. McGraw-Hill Book Company, Inc. 71s. 6d.

"Tonerde und Aluminium." By Wilhelm Fulda, Dr. Phil., und Hans Ginsberg, Dr.-Ing. Habil. II. Teil: "Das Aluminium." 358 pp. inc. name and subject indexes, and 264 illustrations. Berlin, 1953. Walter de Gruyter & Co. Ganzleinen DM 44.

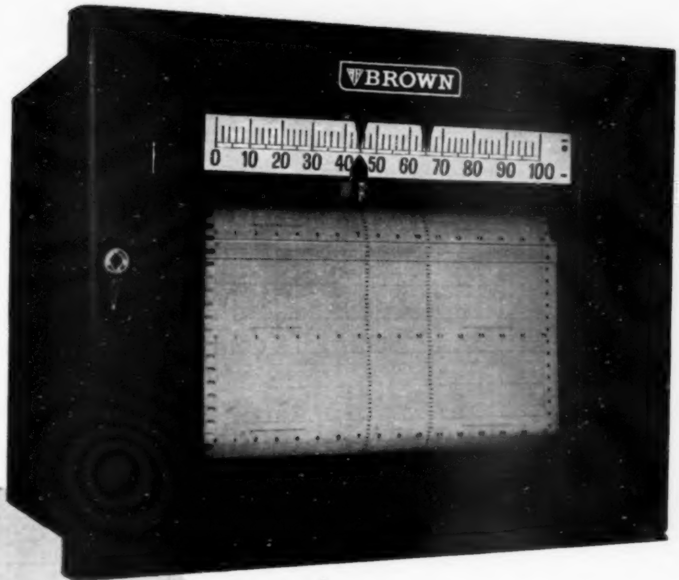
"The Manufacture of Iron and Steel." By D. J. O. Brandt, B.Sc., A.R.S.M., A.I.M. 384 pp. inc. numerous illustrations, London, 1953. English Universities Press, Ltd. Published under the auspices of the British Iron and Steel Federation. 15s. net.

"Industrial Inorganic Analysis." By Roland S. Young, Ph.D., F.R.I.C. 368 pp. inc. author and subject indexes. London, 1953. Chapman & Hall, Ltd. 36s. net.

* The German edition should not be regarded as a mere translation of the English manuscript. In due consideration of the different spheres of interest of the American and German readers, some parts are treated more extensively in the American than in the German edition, and vice versa. The German edition combines in one large volume the contents of the present American book and of one now in preparation dealing with other aspects of the subject.



A COMPACT VERSATILE INSTRUMENT FOR ACCURATE MULTIPLE CONTROL



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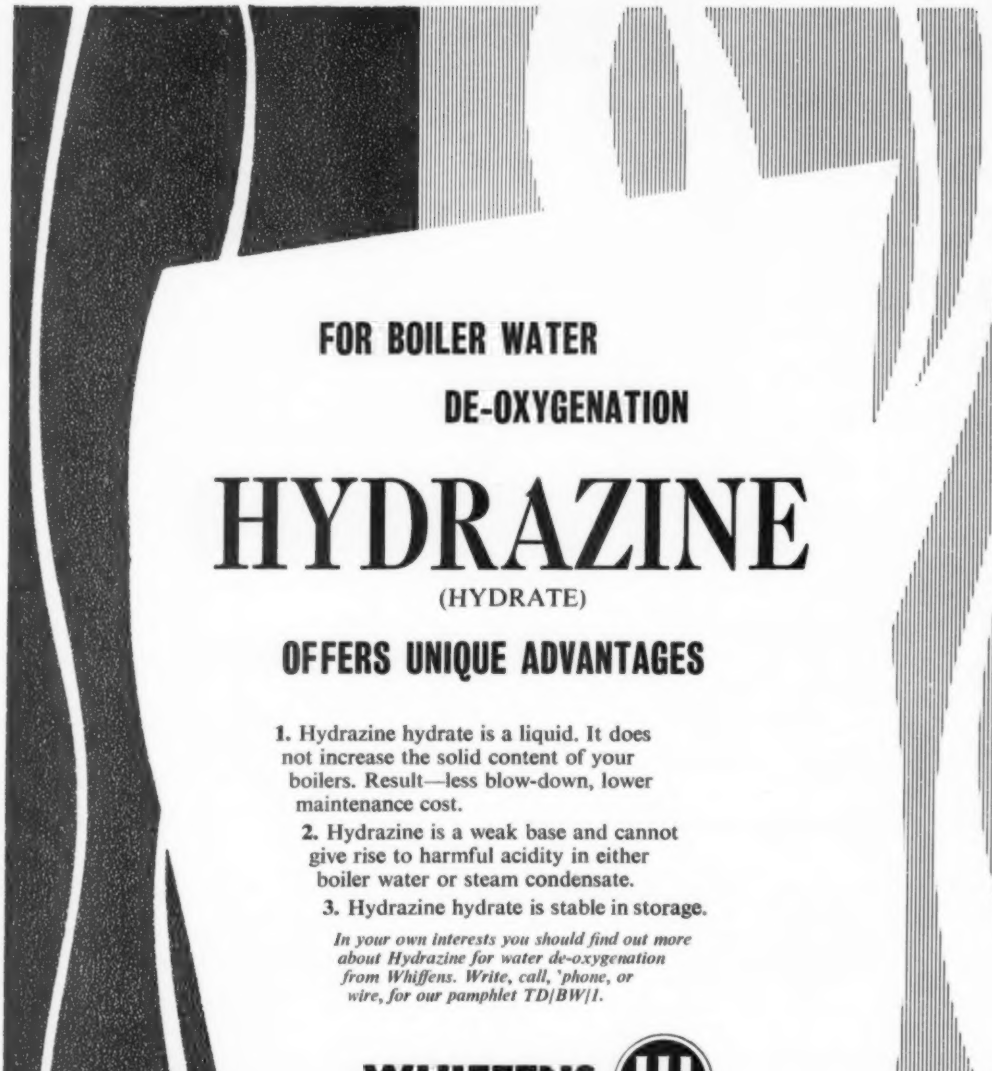
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Use of Perchloric Acid in Electrochemical Analysis

By George Norwitz*

Following reference to the use of perchloric acid in electrolysis with the mercury cathode, the author outlines the part it plays in the electrolytic determination of a number of metallic elements.

IN recent years perchloric acid has become an indispensable reagent in electrochemical analysis. The basic reason for its importance in this field is its inertness: in aqueous solution it is not reduced at the cathode nor oxidised at the anode[2]. In the present paper a survey is made of the use of perchloric acid in electrochemical analysis.

Electrolysis with the Mercury Cathode

Perchloric acid is being used more and more in electrolysis with the mercury cathode[3, 5, 18, 19, 22, 26], although its potentialities in this respect have not been fully realised. The use of perchloric acid in this method of electrolysis has many advantages over the use of sulphuric acid, one of them being that the presence of more perchloric acid than sulphuric acid is permissible when using the mercury cathode, since perchloric acid is about 12 N, while sulphuric acid is about 36 N. A common means for adjusting the acidity prior to a mercury cathode electrolysis is to neutralise with ammonium hydroxide and then add the requisite amount of acid, but this can lead to difficulty due to the formation of puffy ammonium amalgam. When perchloric acid is present rather than sulphuric acid, this adjustment of the acidity by means of the addition of ammonium hydroxide is rarely necessary. The permissible acidity with perchloric acid (or sulphuric acid) depends upon the metal to be deposited. Such elements as copper, zinc and iron are readily deposited from a solution containing up to about 8 ml. of perchloric acid per 100 ml., while for the electrodeposition of chromium only about 0·5 ml. of perchloric acid should be present.

The use of perchloric acid rather than sulphuric acid is recommended when depositing lead into the mercury cathode for the reason that lead perchlorate is soluble while lead sulphate is insoluble. The usefulness of a perchloric acid electrolyte in the removal of heavy metals prior to the determination of barium or sulphur as barium sulphate is self evident.

A procedure commonly used when applying the mercury cathode to metallurgical materials is to dissolve the sample in nitric or hydrochloric acid, or a mixture of hydrochloric and nitric acids, and then evaporate to fumes of sulphuric or perchloric acid to drive off the nitric and hydrochloric acid. The use of perchloric acid in such a procedure is frequently more advantageous than the use of sulphuric acid, as there is less tendency towards spattering, with subsequent loss of material, when perchloric acid is used. Also, the formation of difficultly soluble dehydrated sulphates of iron, nickel, cobalt, chromium and aluminium is avoided. The perchlorates of iron, nickel, cobalt, chromium and aluminium are very soluble, even after strong fuming with perchloric acid. For materials containing more than 5 mg. of tin, the use of sulphuric acid rather than perchloric acid is recommended when a fuming operation is included in the procedure. On fuming a solution containing more than 5 mg. of tin with perchloric acid, metastannic acid is precipitated and cannot be brought back into solution. The metastannic acid will not deposit into the mercury cathode and must be filtered off.

The use of perchloric acid is convenient when it is necessary to eliminate chromium as chromyl chloride prior to the electrolysis with the mercury cathode. Chromium can be deposited into a mercury cathode, but the process is troublesome and time-consuming when more than small amounts of chromium are present. It is best to remove the bulk of the chromium before the electrolysis, by the dropwise addition of hydrochloric acid to the fuming perchloric acid solution[24]. Chromium cannot be volatilised by adding hydrochloric acid to a fuming sulphuric acid solution.

The use of perchloric acid in electrolysis with the mercury cathode is especially important for the colorimetric determination of aluminium in alloys[3, 22, 26].

General Electrolytic Determination of Metals

Bismuth

Bismuth can be accurately determined by electrodeposition from a perchloric acid solution containing hydrazine sulphate[10]. This is an important use of perchloric acid, especially since the deposition of bismuth from a sulphuric acid medium (with or without hydrazine sulphate) is inaccurate[8].

Cadmium

Cadmium can be deposited from a dilute perchloric acid solution[1, 6, 17], as readily as from a dilute sulphuric acid solution. The interference of nitric acid with the deposition of cadmium can be eliminated by prior fuming with perchloric acid[1, 17].

Cobalt

Cobalt can be precipitated with nitroso-beta-naphthol, or with sodium hydroxide and bromine, the precipitate and filter paper dissolved in a mixture of sulphuric, perchloric and nitric acids, and the solution evaporated

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to fumes of sulphuric acid. The cobalt can then be electrolysed from an ammoniacal solution in the regular manner[20]. The perchloric acid must be driven off because of the precipitation of an insoluble pink salt, cobalt ammonium perchlorate.

Copper

Copper has been deposited from a perchloric acid medium[1, 6], a perchloric-nitric acid medium[9, 12, 15], a perchloric-sulphuric-nitric acid medium[1, 25], and a perchloric-sulphuric-phosphoric acid medium[23]. In the analysis of manganese bronze, it has been discovered[12] that copper (and lead) can be separated from up to 2% tin by electrolysing a solution obtained by dissolving the sample in a mixture of nitric and perchloric acids, without heating, and adding hydrogen peroxide to destroy the oxides of nitrogen. If the perchloric acid were omitted, about one-fourth of the tin present would deposit with the copper. Perchloric acid is particularly useful in the analysis of copper alloys by sequence procedures. For instance, after the copper and lead in manganese bronze have been determined by electrolysis from a perchloric-nitric acid solution, as described above, the manganese, nickel, iron and aluminium can be determined colorimetrically, and the tin volumetrically, on aliquots from the electrolyte[12]. In the analysis of Monel metal[9], the sample can be dissolved in a mixture of nitric and perchloric acids and the solution evaporated to fumes of perchloric acid to dehydrate the silicon. The silicon is filtered off and determined, and the copper electrolysed from the filtrate after the addition of nitric acid. Iron is then determined colorimetrically on an aliquot from the electrolyte. In the analysis of silicon bronze hardener[15], a copper-base alloy containing about 20% silicon and 8% iron, the sample is dissolved in a mixture of nitric and hydrofluoric acids, perchloric acid added, and the solution evaporated to fumes of perchloric acid to drive off the silicon and hydrofluoric acid. Nitric acid is added and the copper electrolysed. The electrolyte is evaporated to fumes of perchloric acid, and the iron reduced with stannous chloride and titrated with permanganate.

Lead (as Lead Dioxide)

In the analysis of manganese bronze, lead can be separated from up to 2% tin by electrolysis from a perchloric-nitric acid solution[12]. By the use of a strong perchloric-nitric acid medium, up to 1 g. lead can be accurately determined as lead dioxide[11], whereas by the use of a strong nitric acid solution only up to about 0·1 g. of lead can be accurately determined[7]. The reason for this lies in the fact that the deposition of large amounts of lead as lead dioxide is favoured by very high acidity, and is hindered by the presence of too much nitrate ion. It is obvious why a strong perchloric-nitric acid medium would be superior to a strong nitric acid medium.

Lead can be separated from the interfering elements chloride and bromide by evaporating to fumes of perchloric acid, adding nitric acid and copper nitrate solution and depositing the lead as lead dioxide[16]. If arsenic, antimony or tin is present, it can be removed by evaporating to fumes of perchloric acid in the presence of hydrobromic acid[16]. Interference, by certain reducing materials, with the electrodeposition of lead dioxide can be eliminated by evaporating to fumes of perchloric acid in the presence of nitric acid[16]. Large amounts of chromium interfere with the electrodeposition of lead as lead dioxide[21], but this interference can be eliminated by volatilising the chromium as chromyl chloride from the fuming perchloric acid solution.

Nickel

Nickel can be precipitated with dimethylglyoxime or with sodium hydroxide and bromine, the precipitate and filter paper dissolved in a mixture of sulphuric, perchloric and nitric acids, and the solution evaporated to fumes of sulphuric acid. The nickel can then be deposited from an ammoniacal solution in the usual manner[20]. The perchloric acid must be driven off because of the precipitation of an insoluble purple salt, nickel ammonium perchlorate.

Silver

Silver has been deposited from a perchloric acid medium[1, 6]. It can be precipitated as the chloride, the precipitate and filter paper dissolved in a mixture of sulphuric, perchloric and nitric acids, the solution evaporated to fumes of sulphuric acid, and the silver electrolysed from an alkaline cyanide medium[13]. The perchloric acid must be driven off, otherwise the silver chloride will not dissolve.

Tin

Tin can be precipitated as the sulphide or as metastannic acid, and the precipitate and filter paper dissolved in a mixture of sulphuric, perchloric and nitric acids. The solution is then evaporated to fumes of sulphuric acid and the tin electrolysed from a sulphuric-hydrochloric acid medium in the presence of hydroxylamine hydrochloride[14].

Zinc

The interference of nitrate with the electrolysis of zinc from a sodium hydroxide or an ammoniacal medium can be eliminated by prior fuming with perchloric acid.[1]

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Metal Melting Under Vacuum

Some Mechanical Problems Involved

Fig. 1.—G.A.B. vacuum melting plant.

THE melting of metals under high vacuum is a process of comparatively recent development, but during and since the last world war it has progressed from the initial stages of laboratory experiments with small and makeshift equipment until at the present time a standardised range of sizes is available having crucible capacities from 20 to 240 lb., with accompanying high-vacuum pumping equipment suitable for vacua of the order of 10^{-5} mm.Hg., and there is today a plant installed in a Swiss works with a crucible capacity of 450 lb. steel.

The Container

It will be appreciated that the design and construction of the outer vacuum vessel or container which surrounds the furnace proper presents a number of problems, especially in view of the fact that in a well-designed plant the melting should be carried out as far as possible under the same conditions as any other installation working at atmospheric pressure. In the case of the plant illustrated by Fig. 1, which is a 60 lb. standard installation made by the Swiss firm Geraetebau-Anstalt Balzers of Liechtenstein, the container is made of stainless steel, double-cased, with a large hinged cover, both body and cover being intensively water-cooled. In general, the time required for the production of a vacuum in such a vessel depends not only upon the internal capacity of the container, but also upon the dimensions, composition, and quality of the internal surfaces, which should have smooth and flowing lines and be capable of being readily cleaned. Some of the problems which have to be solved in the design of such a container are: (1) the provision of means for charging the various constituents of an alloy in the proper order and at the appropriate stages in the process; (2) observation and measurement of the temperature of the melt; and (3) means for pouring the charge.

In the design of the furnace illustrated, the problem of obtaining access to the crucible for the addition of various constituents during the progress of the melt is overcome by the provision in the main cover of the container of a supplementary 6-chamber rotary hopper which is situated directly above the crucible, and can be turned by means of an external handle so that each of the compartments can be brought successively over a charging hole, through which the contents of the compartment are dropped on to a hinged shovel immediately beneath. The actuation of another external lever allows the shovel to be tipped and to slide the charge into the crucible.

Fig. 2.—Pyrometer withdrawn from crucible.

Temperature Measurement

Observation of the progress of a melt is a difficult matter in a vacuum plant because, owing to the heavy vaporisation of the charge, a normal inspection window would be quickly obscured by a metallic deposit. In the plant described, there is an inspection window of quartz glass in the hinged cover, which is reinforced internally by a second window in Pyrex. The latter is protected to a considerable extent against the deposition

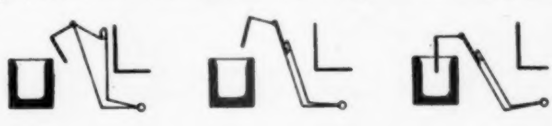

Fig. 3.—Method of inserting pyrometer in crucible.

of metallic vapour when not in use by a movable guard, and can be cleaned of any such deposit by a wire wiping brush operated by an external lever. However, advantageous as visual observation is, the method is naturally no substitute for accurate pyrometric measurement, and although the use of an optical pyrometer is not possible, an ingenious method has been devised for readings to be taken by a thermo-couple, as shown in Fig. 2. By means of a spring mounting arrangement, this couple (in a quartz protecting tube) is normally maintained alongside the crucible where it is not liable to either mechanical or thermal damage, and in this position it does not interfere either with the charging or tilting of the crucible. It is inserted into the crucible by the simple movement of an external hand lever in the manner shown by the diagrams in Fig. 3.

Pouring

Various possibilities have been tried for pouring a molten charge of metal inside a vacuum container, in some of which tilting of the entire container is necessary, which involves the movement of considerable masses. Other methods include one in which the metal is run off through the bottom of the crucible by the withdrawal of a taper plug, but this system can only be adopted in cases where it is possible to use a graphite crucible. A German solution of this particular problem involves the sealing of the bottom of the crucible by a plug of the same metal as that which is being melted, this plug being in its turn melted by an auxiliary heating coil.

The method adopted in the plant shown in Fig. 1 can be seen from the sectional view Fig. 4, in which it will be noticed that in this case it is only the crucible which tilts. Induction heating is employed in this case, the method permitting of the crucible being moulded and fired *in situ*, and as it is of the lip-tilting type, the molten charge is poured directly into the mould located immediately beneath the lip without any necessity for movement or adjustment of the mould during the progress of the pour.

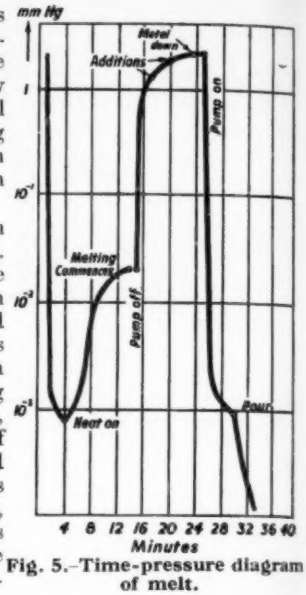

Fig. 5.–Time-pressure diagram of melt.

The ingot mould also presents certain difficulties in vacuum melting. In this process, it is naturally not feasible to employ sand moulds unless it is possible for these first to be heated under vacuum and completely de-gassed, otherwise the gases disengaged in contact with the metal would be liable to result in a porous casting. In the plant illustrated, the moulds usually employed are of cast-iron or steel, having perfectly smooth surfaces, and pre-heated to some 300° C. The ingot mould is attached to a vertical stand having adjustable arms so that the stand will serve for a variety of moulds of different sizes. Provision is made for these to be water-cooled if necessary.

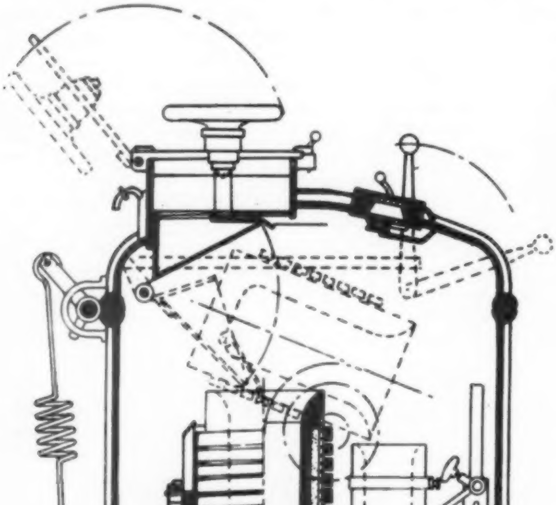

Fig. 4.—Sectional view of vacuum melting plant.

The Melting Process

The diagram Fig. 5 will enable the progress of a typical melt to be followed, this particular instance being the melting of 11 lb. of tool steel (0·45% C, 1·2% Cr, and 0·15% V) previously melted under atmospheric pressure. The crucible employed was of magnesium oxide. Four minutes after closing the container a pressure of 8×10^{-4} mm. Hg. was reached, and heating of the charge commenced. The pressure rose sharply from this point, due to gases given off by the crucible and the charge, the pump being switched off immediately after the commencement of melting as the reaction between the oxygen and carbon in the melt was so strong that metal was thrown out of the crucible. Additions to the charge were made at the points indicated, and when all the material was brought down and the melt quiet, pumping was resumed. Energy consumption for melting under a high vacuum is for all practical purposes the same as for an equivalent charge melted in the same type of furnace under atmospheric pressure, and it will be seen from the diagram that the production of the preliminary vacuum has very little effect upon the time factor, the main difference in the time being dependent upon the extent to which it is desired to push the degassing of the charge.

A Rapid Compleximetric Method for the Determination of Magnesium in Aluminium Alloys

By J. Clive Sergeant

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A rapid titrimetric method of determining magnesium in aluminium alloys, using di-sodium ethylene diamine tetra acetic acid (E.D.T.A.) with Eriochrome Black as indicator is described.

THE rapid growth of the aluminium industry has brought about the development of many new alloys, so that today alloying quantities of magnesium are to be found, ranging from the L.M.14 "Y" alloy (1·2–1·7% Mg.), to the L.M.5 (3–6% Mg.), and L.M.10 (9·5–11% Mg.). Many methods are available for the determination of the element[1,2,3] including the pyro-phosphate, the standard oxine, the rapid oxine, and the Titan Yellow and Solochrome Cyanin colorimetric methods.

These have given satisfaction in their field of application but, unfortunately, they either require considerable time, such as in the case of the pyro-phosphate and standard oxine methods ; or considerable skill, as in the rapid oxine method ; or they can only be used to determine small amounts, as in the case of the colorimetric methods.

It became increasingly evident that an accurate, speedy, and easily operated method was needed, which would not only handle the larger number of determinations required, but would also be suitable for furnace control work, when the more difficult alloys of the L.M.10 type were being produced.

First attempts were made to use a method of separating and complexing interfering elements, terminating in a single oxine precipitation, with a titrimetric finish. Manganese, however, proved to be troublesome, and when a separation was finally evolved, it was found that one of the reagents interfered with the formation of magnesium oxinate. It was then that the titration of magnesium using di-sodium ethylene diamine tetra acetic acid (E.D.T.A.)[4,5] was brought to the author's notice, and the possibility of adapting it to the existing method presented itself.

Procedure

In the chosen method, a standard sodium hydroxide attack is employed, to remove the bulk of the aluminium, silicon, and zinc. The residues containing the magnesium, after being filtered off and washed, are boiled in dilute sulphuric acid, thus finely dividing the copper, and freeing any entrapped magnesium : the copper residue is then filtered off. After ammonium chloride has been added to hold up the precipitation of the magnesium, the manganese is separated from a slightly ammoniacal solution by oxidation with bromine in the presence of sodium acetate. Chromium and aluminium, as well as iron, etc., are also removed at this stage by filtration, otherwise they interfere with the titration. More ammonia is then added, and any copper and/or nickel remaining is complexed with potassium cyanide. The solution is then ready for titration. Temperature control is not necesssary, although Flaschka,[6] when titrating micro amounts of zinc with the reagent, adjusts the temperature to 50–60° C., so as to ensure a sharp end-point.

Reagents

(1) *Sodium Hydroxide Solution*—30% w/v in water.

(2) *Sulphuric Acid*—5% v/v sulphuric acid (S.G. 1·84) in water.

(3) *Ammonium Chloride*—Solid A.R. quality reagent.

(4) *Bromine Water*—Saturated solution.

(5) *Ammonia Solution*—S.G. 0·880.

(6) *Sodium Acetate*—Solid A.R. quality reagent.

(7) *Potassium Cyanide Solution*—20% w/v in water.

(8) *E.D.T.A. Solution* (N/10)—Dissolve 19 g. of E.D.T.A. in water and make up to 1 litre.

(9) *Eriochrome Black Solution*—Dissolve 0·5g. reagent and 4 g. hydroxylamine hydrochloride in 100 ml. of alcohol and filter.

(10) *Accelerator Pulp*—Shake 12 pieces of Whatman 1 in. $\times$ $\frac{3}{4}$ in. accelerators in 30–40 ml. water in a 500-ml. reagent bottle and make up to 500 ml.

(11) *Distilled Water*—Used throughout the method.

Method

Attack the sample with sodium hydroxide solution (30%). When digestion is complete, dilute to about 200 ml. with water, add a small pinch of filtering pulp, and bring to the boil. Filter on to a sintered funnel of No. 2 porosity, to which has been added some accelerator pulp (fill the funnel with pulp solution, and remove the water by suction). Wash 4–5 times with a hot solution made just alkaline to litmus with sodium hydroxide, to ensure the maximum removal of aluminium, silicon, and zinc. Moisten the pulp with water and transfer it to the original beaker using a thin glass rod. Wash round the funnel and glass rod with hot water into the beaker, add 15 ml. of dilute sulphuric acid (5%), and simmer for one or two minutes. Re-filter through the original funnel, and wash four times with small amounts of hot water, transferring the solution to the orginal beaker.

Next add 6–8 g. of ammonium chloride, and 5 ml. bromine water, bring to the boil for one or two minutes, and add sufficient ammonia (S.G. 0·880) to decolourise the solution (approx. 3 ml.). Finally, add a further 20 ml. of bromine water, plus 2–3 g. of sodium acetate, and a pinch of pulp, and boil for a further one or two minutes.

Filter through a pulp pad to remove the precipitates of manganese, chromium, aluminium and iron, wash four times with small amounts of hot water, and transfer the solution to the original beaker. Add 5 ml. of ammonia (S.G. 0·880), and sufficient potassium cyanide

solution to decolourise any copper and nickel present; finally add 9–11 drops of Eriochrome Black from a dropping bottle, and titrate from red, through purple, to a blue end point with the E.D.T.A. solution.

1 ml. N/10 E.D.T.A. = Approx. 0·00125 g. Mg.

Notes

(i) For 3–12% Mg.—Attack 0·2 g. sample with 15 ml. sodium hydroxide solution in a 400-ml. "tall form" beaker.
For 1–3% Mg.—Attack 0·5 g. sample with 25 ml. sodium hydroxide solution in a 400-ml. "tall form" beaker.
For 0·5–1% Mg.—Attack 1 g. sample with 35 ml. sodium hydroxide solution in a 400-ml. "tall form" beaker.
For 0·5% Mg.—Attack 2 g. sample with 50 ml. of sodium hydroxide solution in a 600-ml. "tall form" beaker, reverting to a 400-ml. beaker after the filtration of the residues.

(ii) When large amounts of chromium are present in the alloy, 3–4 g. of sodium peroxide added cautiously before the end of the initial attack will oxidise it to a soluble chromate.

(iii) A vacuum pump is essential for the filtrations.

(iv) When carrying out titrations, it is worth noting that a little magnesium solution in dilute sulphuric acid, will re-develop the red colour.

(v) For normal work, a 25-ml. burette is used, but for very small amounts a 5-ml. micro-burette is recommended.

(vi) To standardise E.D.T.A., take approximately 0·2g. of pure magnesium metal, record the exact weight, dissolve it in a little dilute sulphuric acid, and make up to a 100-ml. Pipette out 10-ml. aliquots into titration beakers, dilute to 50–60-ml. with water, add 2–3 g. of ammonium chloride, 5-ml. of ammonia (S.G. 0·880), and titrate in the usual way.

(vii) Calcium interferes with the titration, and titrates as magnesium.

(viii) When sintered funnels are in constant use, they gradually become clogged, owing to insoluble inclusions remaining on the surface of the filter disc. This can be overcome by lightly stirring the sintered glass surface with a smooth glass rod whilst immersed in running water. After use, the funnels must always be washed out by passing hot *aqua regia* through them.

(ix) When applied to furnace control work, the following adaption of the method is useful :—
Attack the sample in the usual manner, filter the residues on to a pulp pad, wash normally, then transfer the whole pad to the original beaker. Wash out the funnel with 30–40-ml. of hot water, into the beaker, add 15-ml. of dilute sulphuric acid (5%), and boil for one minute, stirring with a glass rod to break up the pad. Add the ammonium chloride and bromine water, and carry out the manganese separation, and the magnesium titration as described in the standard method.

(x) When small amounts of magnesium have to be determined in the presence of large quantities of silicon, the sample should be attacked in *aqua regia*, the silicon filtered off, and magnesium, etc., precipitated with an excess of sodium hydroxide. The standard method can then be applied.

Results

Typical results obtained by the use of the method on a range of aluminium alloys are presented in the following table.

Sample Used	Magnesium—per cent.	
	Present	Found
ALAR. D.T.D. 424 Standard	0·32	0·323 0·324
ALAR. D.T.D. 424 Standard	0·04	0·044
ALAR. D.T.D. 133C. Standard	0·11	0·113
"Y" Alloy	1·42	1·42 1·43
L.M.5 Alloy	6·03	6·01 6·05
L.M.10 Alloy	11·30	11·27 11·34
L.M.10 Alloy	11·76	11·80 11·73

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Conference on Defects in Crystalline Solids

THE H. H. Wills Physical Laboratory of the University of Bristol, in co-operation with the International Union of Pure and Applied Physics (particularly its Commission for the Physics of the Solid State) and with The Institute of Physics, is organizing a conference on "Defects in Crystalline Solids" to be held from July 13th to 17th, 1954, in Bristol. While not excluding other subjects in the field, the organizers propose to give particular attention to defects such as dissolved atoms, vacancies and F-centres, to microwave resonance methods of investigating their properties, and to the way in which they re-act with dislocations. Thus, dislocations will be discussed in their chemical aspects, as influencing diffusion and precipitation in the solid state; rather than in relation to plastic flow. It is hoped that a number of authors from overseas will personally present their papers, and with this in mind the Conference has been arranged to follow immediately after the General Assembly of the International Union of Pure and Applied Physics.

Board and lodging will be provided in Wills Hall, a student hall of residence, on special terms, or at hotels. The Conference is open to any scientist interested in this field, subject to the limitations of seating accommodation. Further particulars may be obtained from the Secretary, H. H. Wills Physical Laboratory, Royal Fort, Bristol 8, or from the Secretary, The Institute of Physics, 47, Belgrave Square, London, S.W.1. Those wishing to attend the Conference are asked to apply to the former, marking the envelope "1954 Conference," stating whether they wish to be accommodated at Wills Hall or at an hotel and for what nights accommodation is required.